SYSTEMATIC REVIEW

ROLE OF EXERCISES IN IMPROVING STATIC, DYNAMIC AND FUNCTIONAL BALANCE IN CEREBRAL PALSY

ABSTRACT

AIM
To rule out the effectiveness and essence of exercise interventions for improving static, dynamic and functional balance in Cerebral Palsy (CP) patients

METHOD
American Academy of Cerebral Palsy and Developmental Medicine (AACPDM) guidelines was used to formulate the review. Six databases were searched (Pub Med, Google scholar, Cochrane, CINAH, PEDro, Scopus) using a total number of 28 studies reporting 13 exercise protocols with functional, static and dynamic postural controls

RESULTS
Five protocols received moderate level of evidence where Treadmill training with little or no body support, Hippotherapy, Gross motor training, Trunk-targeted training, reactive balance training. Six treatment protocols had shown weak or conflicting evidences such as Neuro-Developmental Therapy (NDT), Hippotherapy simulators, Electrical stimulation usually know as Functional Electrical Stimulation (FES), treadmill training with full or partial body weight support, visual biofeedback (using mirror) and virtual reality.

CONCLUSION
The therapeutic exercise based treatment to improve the overall balance of CP children has remarkably increased since last decade. More studies are suggested to be conducted in order to establish a strong relation between intervention and the outcomes on postural controls. Moreover, future researches must rule out the outliers by standardizing the protocols that are lacking in present studies.

KEYWORDS
Cerebral Palsy, Postural Control, Functional Balance, NDT, BWSTT, Hippotherapy, FES.

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[Khan A, Khan AA. Role of Exercises in Improving Static, Dynamic and Functional Balance In Cerebral Palsy. Pak. j. rehabil. 2017;6(2):4-13]

INTRODUCTION

Cerebral Palsy a non-progressive, motor disability caused by damaged to the developing brain, common in 2 per 1000 children[1,2]. The prevalence of CP has remained remarkably stable over the last 30 years[3]. Literature reveals that almost 80% of Cerebral Palsy are spastic, causing limitations in activities of daily livings, impairment in motor function, gait and balance[4]. The upper motor neuron lesion in the brain damages the functionality of nerve receptors in the spine to properly receive Gamma Amino Butyric Acid (GABA) that intern leads to hypertonia of the muscle supplied by those damaged nerves[4]. One of the most common spastic diplegic are ambulatory with abnormalities like excessive planter flexion at ankle joint and excessive knee flexion associated with adduction and internal rotation at hip joint hence influencing the static and dynamic balance[5]. Maintaining posture is an essential task for balance control among CP children. Although it is a complicated activity to maintain body weight within the base of support during standing, sitting, walking and performing activity but the team of rehabilitation has found effective results[6,7].

Postural instability constitutes the major impairment in motor development, these children has shown number of limitation while performing dynamic and static activities[8]. Usually the functional balance is determined through vision integration, proprioceptive sensation, vestibular and commands from brain [8,9]

Santos MJ et al in his work emphasized on the role of anticipatory postural adjustments in compensatory control of posture during the static stability. 8 subjects were exposed to external predictable and non-predictable perturbations induced at the shoulder level [10].

While when individual is moving (e.g when walking or running or maintaining position over unstable surface) will be considers as dynamic stability, internal perturbation (like walking) and external perturbations (like being pushed by others or an object) are also the components of dynamic stability11 whereas maintaining the optimal functional relationship between body segments, environment, task and environment is known as postural orientation [12,13]

Numerous theoretical frameworks of core functional balance are currently present, out of which the contemporary systems control theory is comprehensive [12,14]. Shumway-Cook et al in the research proposed that the contemporary systems control theory which describes functional balance as a multifaceted interface between seven components such as individual sensory systems, musculoskeletal components, adaptive mechanism, neuromuscular synergies, sensory strategies, anticipatory mechanisms [12]. These deficits in one or more components can be seen in children with motor disorders. Likely interventions and outcomes can target one or more components.

Relating to the children with cerebral palsy, numerous researches on functional balance intervention was conducted during the era of 2000. Campbell at el published a non-systemic review of the exercise protocol for the individuals with cerebral palsy where the essence of NDT, horseback riding (hippotherapy), gait training with auditory stimulation or verbal feedback and inhibitory casting were highlighted[15]. Westcott and Burtner later presented a 2nd, non-systematic review of individuals with motor disabilities using the systems control method[16]. There reviews also supported the work by Campbell with some new suggestions that includes anticipatory balance training via computer feedback and reactive balance training via platform perturbations[15]. However, there were conflicting and insufficient evidences regarding the outcomes of interventions targeting electrical stimulation used in motor system, vestibular stimulations used in sensory system and strengthening programs in musculoskeletal system[16] Further studies were recommended by the authors to improve the existing body of research that included the outcome measures for functional balance and motor function and more task-specific training to improve functional outcomes. Harris and Roxborough 2005, presented a systematic review of functional balance interventions for CP children to examine the efficacy and effectiveness of postural control[17]. Westcott SL and Burtner P had supported the work performed by Campbell[15,16]. The recommendations and outcomes of these reviews urged the study of other new clinical techniques for treating balance in CP[18-21]. However, it has been a decade since the last review on balance among the CP; therefore, it was essential to re-evaluate the efficacy and effectiveness of traditional and classical exercises. The rationale was to provide a review determining the effectiveness and efficacy of the interventions used in the international markets on functional, static, dynamic balance among the people with CP and also to emphasize on its utilization in the current market

METHODOLOGY

The guideline of American Academy of Cerebral Palsy and Developmental Medicine (AACPDM)[21] were used to for formulating this review.

Search Strategy

A systemic literature search of articles published between October 2000 and October 2016 was performed using the databases; Google Scholar, the Cochrane, PubMed and PEDro. Search included Cerebral palsy, functional balance, static

balance, dynamic balance and intervention as their main keywords using different Boolean logic

Inclusion and Exclusion Criteria

The following inclusion criteria was used while selecting the studies for the review

1. All peer-reviewed journals after 2000, published in English; 2. Participants were diagnosed CP with aging between 1 to 18 years old; 3. They reported the effectiveness and efficacy of the intervention for the improvement of static, dynamic and functional balance.

Following was the exclusion criteria 1. Patient using Botox injections 2. Recent surgery relating to cerebral palsy 3. Exercise without any outcome; 4. Water- based interventions.

RESULT

A total of 250 articles were distinguished, 220 from primary searches, and 30 from secondary searches. After duplicates were eliminated, 120 articles were evaluated with their titles and abstracts. Of these, 75 articles met initial criteria and were reviewed, with 28 studies meeting our inclusion criteria.

From the 28 included studies (evidence levels I-V) 25 type of interventions were determined that supported the effect of intervention on the static, dynamic and functional balance among cerebral palsy. Studies include Neuro Developmental Technique (n=6), Hippotherapy (n= 5), Virtual Reality (n=3), Systemic Review (n=3) which include (NDT, hippotherapy, Reactive balance), Functional Electrical Stimulation (n=2), Reactive balance (n=2), Treadmill training (n=2), Gross Motor Task Training (n=2), Progressive resistance training (n=1), Trunk-Targeted Training (n=1), Visual Biofeedback (n=1).

Results were tabulated based on American Academy for Cerebral Palsy and Developmental Medicine guidelines. Articles that were ranked as level I to III (n=2) met criteria for full assessment, which is provided in table 1. It includes citation, level of authentication by evidence, participants characteristics (type and level on GMFCS), intervention, results and outcome measure.

Table 1

Study/Author	Level of Evidence	Intervention	Participants	Results	Outcome measure
FES Park.et al.[22]	Group II, weak	FES	CP.(Spastic. diplegia) mean .age=13	Improved postural symmetry in sitting (Cobb and Kyphoticangle, p<0.05) ,no change in lumbosacral angle	Radiographic Measures; Cobb, Kyphotic and Lumbosacral angle
FES Karabay et al [23]	Group II, Weak	FES	CP (Spastic diplegic)	Improved postural symmetry in sitting (Cobb. Kyphotic and sacral angle p<0.001)	Radiographic measures; Cobb, Kyphotic and sacral angle
GMTT Katz-Leurer et al[24]	Group II, Moderate	Gross motor task training	TBI & CP	No change in strength Muscle No change in walking efficiency Improved dynamic balance in standing &walking	Muscle strength (dynamometry) Walking speed over10 meters. For functional balance Timed-up and go test
GMTT Salem & Godwin[25]	Group II, Moderate	Gross motor Task training	CP	Improved gross motor function; standing (P=0.009)and walking, running and jumping (p=0.007) Improved dynamic balance	Timed-up and go test
Hippotherapy Kang et al [26]	Group II, Weak	Hippotherapy	CP(hemi-and diplegic ambulatory)	Improved sitting balance (p<0.05).	Stabilometry, Pathway and velocity of COP while sitting still for 30s
Hippotherapy Hamill et al[27]	SSRD III, Moderate	Hippotherapy	CP; GMFCS V	No change in sitting functional balance No change in gross motor function overall, or in sitting.	Sitting Assessment Scale GMFM-88; B (sitting) and total score

Study/Author	Level of Evidence	Intervention	Participants	Results	Outcome measure
Hippotherapy Kwon et al[28]	Group III, Moderate	Hippother-apy	CP;GMFCSI-II	Improved walking (stride length p<0.001 and walking speed p=0.002) Change in cadence, single limb support, or pelvic and hip kinematics Improved overall gross motor function (P=0.003); Improved balance in standing.	Temporal-spatial and kinematic gait parameters Paediatric Balance Scale
Hippotherapy Borges et al[29]	Group II, Weak	Hippother-apy	CP(Spastic Diplgic)GMF CS II-IV	Improved functional balance in sitting No change GMFCS	Stabilometry,Volun-tary COP move-ment in sitting
Hippotherapy Herrero et al [30]	Group II, Strong	Hippother-apy Simulator	CP; GMFC-SIIV	No change in sitting control Improved sitting function. No change in GMFCS	Sitting Assessment Scale GMFM-66
NDT Park et al. [22]	Group II, Weak	NDT	CP (Spastic diplegic)	Improved postural symmetry in sitting (Cobb angle only p<0.05) No change in kypphotic and lumbosacral angle Improved sitting function	Radiographic measure; Cobb angle GMFM;
NDT Salem and Godwin[25]	Group II, Moderate	NDT	CP(quadri-plegic and diplegic) GMFCS I-III	Improved gross motor function; Improved dynamic balance	Timed- up and go test
NDT Borges et al[29]	Group II, weak	NDT	CP (Spastic diplegia) GMFCS II-V	Improved postural control No change in motor classifi-cation	Stabilometry; Voluntary COP movement in sitting GMFCS
NDT Karabay et al[23]	Group II, weak	NDT	CP (Spastic dipegia)	Improved postural symmetry (p<0.003) Improved sitting (p<0.001)	Radiographic measure; Cobb angle GMFM;
NDT El-Shamy et al[31]	Group II, Moderate	NDT	CP (Spastic dipegia)	Improved limits of stability (p<0.001) Improved falls risk (p<0.05) Improved functional balance	Biodex, DSL level 12; movement of COP with visual feedback Biodex; COP pathway in response to perturbation calculation of falls risk
NDT Kwon et al.[28]	Group III, Moderate	NDT	CP (bilateral spastic)	Improved walking, (cadence p=0.013, walking speed-p=0.002) No change in cadence, single limb support, or pelvic and hip kinematics	Temporal-spatial and kinematic gait parameters Paediatric Balance Scale
PRE Bandholm et al.[32]	Group II, Strong	Progressive resistance training	CP; GMFCS I	Improved planter flexion MVT only (p<0.035) No change in gait pattern No change in static balance (standing) No change in gross motor performance	Ankle muscle strength 3D gait kinematics and temporalspatial parameters Stabilometry; GMFM-66
Reactive balance El-Shamy et al.[31]	Group II, Moderate	Reactive balance	CP (Spastic diplegic) GMFCS I-II	Improved limits of stability (p<0.001) Reduce falls risk (p<0.05) Improved functional balance (P<0.05)	Biodex, DSL level 12 Paediatric Balance Scale

Study/Author	Level of Evidence	Intervention	Participants	Results	Outcome measure
Reactive Balance Shumway-Cook et al.[33]	SSRD II, Moderate	Reactive Balance training	CP; GMFCS I-II	Improved reactive balance in standing No change in function in standing	Stabilometry GMFM
Systematic Review Harris and Roxborough[17]	Systematic review, II 8/9	Motor training and balance training NDT Hippotherapy Rocker board training Reactive balance training	12 studies; CP	Improved balance by motor training Conflicting results for NDT Improved balance by reactive balance training Improved balance by hippotherapy Improved balance by rocker board training	GMFM Stabilometry Paediatric Balance
Systemic Review Zadnikar and Kastrin[34]	Systematic review II 9/9	Hippotherapy & Therapeutic horse riding	8 studies; CP	Improved functional balance (various) with all interventions.	Video, dynamic trunk/ head stability, barrel test, function reach test, posture assessment scale, GMFM Bruininks-Oseretsky Test of Motor Proficiency
Systemic Review Tseng et al.[35]	Systematic review II 8/9	Equineassisted activities and therapies (EAAT) Hippotherapy and therapeutic horse riding	14 studies; CP	Improved functional balance by hippotherapy No change in GMFCS	Betoti's Postural Assessment scale Modified Ashworth Scale GMFM-66
Treadmill training Dru_zbick et al.[36]	Group II, Weak	Treadmill training	CP; GMFCS IIIII.	Improved standing balance, ($p<0.05$) Improved weight symmetry in standing	Stabilometry Underfoot pressure distribution
Treadmill training Grecco et al.[37]	Group II, Moderate	Treadmill training	CP;GMFCS I-II	Improved standing balance ($p=0.03$) Improved functional balance in standing ($p=0.01$)	Stabilometry Berg Balance Scale
Trunk-Targeted Training Unger et al.[38]	Group II, Moderate	Trunk targeted exercise	CP; GMFCS IIII	Improved postural alignment ($p<0.05$) Improved abdominal muscle thickness Improved abdominal muscle strength Improved functional walking ability	2D photographic posture analysis in standing Ultrasound imaging: Total sit-ups in one minute One minute walk test

Study/Author	Level of Evidence	Intervention	Participants	Results	Outcome measure
Virtual Reality Ramstrand and Lygneg_ard.[39]	Group II, Weak	Virtual reality: Nintendo Wii, Wii Fit and Wii balance board	CP; GMFCS I-II	No change in standing balance No change in reactive balance No change in directional control	Stabilometry Pediatric Balance scale Rhythmic Weight shift test
Virtul Reality Jelsma et al.[40]	SSRD II, Strong	Virtual reality: Nintendo Wii, Wii Fit and Wii balance board	CP; GMFCS I-II	Improved balance in standing ($p<0.05$) No change in running	Bruininks-Oseretsky Timed-up and down stairs test
Virtul reality Brien and Sveistrup[41]	SSRD III, Strong	Virtual reality; 2D virtual world	CP; GMFCS I	Improved high level functional balance and mobility in everyday function Improved functional walking capacity No change in functional mobility No change in gross motor functionImproved	Community balance and mobility scale 6-min walk test GMFM
Visual biofeedback Ledebt et al.[42]	Group II, weak	Visual biofeedback	CP; GMFCS I	static and dynamic standing Improved gait ($p=0.015$)	Stabilometry 4m walkway with two force plates

Functional Electrical Stimulation (FES)
Studies by Perk E[22] and Karabay I[23] showed that evidence level II applied Functional Electrical Stimulation (FES) to abdominal and lumbar muscles together, aiming to improve the function and strength of muscles. Both studies used the FES parameters with a pattern of 10 secs 'ON' followed by 10 secs 'OFF'. Intensity of 20 to 30 mA; pulse width of 2501 µs and frequency of 25-35 Hz along with the conventional physical therapy (including stretching, gait training, NDT). FES improves the static posture[22,23].

Gross Motor Task Training (GMTT)
These exercises are the collection of general functional motor exercises such as walking and standing activities, reaching sit to stand, and step-ups[24]. Sit to stand and step up exercises helps in improving standing balance and dynamic postural stability during gait in children with CP[25].

Hippotherapy
Hippotherapy is provision of motor input and sensory through movement of artificial horse, and programs designed by professionals[33]. In sitting and standing balance improvement was seen for school-aged ambulant children whereas no improvement was seen in non-ambulant[26]. Meanwhile two systematic reviews have revealed that mild spastic CP shows more improvement as compare to severe spastic CP following Hippotherapy[27].

Neuro Developmental Therapy (NDT)
NDT depends on Bobath technique was used along with the conventional therapy. NDT was found to be effective in improving postural balance including standing balance and activity in diplegic[28] whereas it fails to improve dynamic balance, speed in spastic diplegic and quadriplegic[29].

Progressive Resistance Exercises (PRE)
Progressive resistance exercises include lifting weights, resisted motion. Studies have revealed that no effects on functional balance among cerebral palsy has been observed[32].

Reactive balance training
It includes repetition of balance recovery, when standing on a mobile surface that can move in any direction. Studies showed improvement in stability (static balance), standing balance and reduce risk of fall in spastic cerebral palsy[31,33].

Treadmill training
Walking or running on Treadmill, training on a treadmill with varying speed, with no body weight supported, partial body weight supported and full body weight supported. Studies reveals that results of no body weight supported training on treadmill showed an improvement in standing balance and overall balance in spastic ambulant CP[36]. Meanwhile with full and partial weight supported treadmill training among the spastic ambulant and semi-ambulant CP has shown improvement only in

standing balance[37].

Trunk-Targeted Training (TTT)
Trunk-targeted training mostly focused on the improvement of trunk muscle control and strength. Protocol of these articles revealed improvement in postural alignment, increase in thickness of abdominal muscles with improvement in muscle strength[38].

Virtual Reality
It includes the balance training with the use of video games to create a virtual environment by using artificial sensory information to stimulate real life experiences or activities. Improvement was seen in standing balance and during activity when under supervision this training was done[39,40]. Meanwhile no improvement was seen when the task were completed at home[41].

Visual biofeedback
Only one study was included in this systemic review about standing on a balance board and keeping the center of pressure, represented as a red dot on a computer screen. Improvements in standing and dynamic balances were observed[42].

DISCUSSION

Current systemic review analyzes 27 children's CP studies and determines the use of different posture control interventions. There was sufficient evidence found which supports the use of five of these interventions that is treadmill training without body weight support, hippotherapy, trunk-specific training, reactive balance training and gross motor task training. Partial or full body weight support treadmill training, neurodevelopmental technique, virtual reality, visual biofeedback and functional electrical stimulation have found little conflicting evidence to support the studies.

Results shows that posture control in progressive resistance exercises did not improve (P=0.122)[32]. Mobile CP children with the GMFCS I-III were included in all the studies except in neurodevelopmental technique. Of all interventions hippotherapy is the most commonly used intervention protocol[43]. Multiple variations were made to obtain the desirable result like multiple posture control components, including expectations and reactions posture adjustment, sensory and musculoskeletal system [44]. Sensory input was introduced like warm and rhythmic horses to improve balance, posture and strength[34]. Hippotherapy was proved to be effective in improving muscle control of trunk (P=0.05). In the light of systemic review hippotherapy was found more effective for mobile children's CP (GMFCS I-II) rather than more severe CP [34,35]

Treadmill training without body weight support has shown a little improvement in functional balance whereas progressive resistance exercise (Level II study) [32] were found to have no therapeutic effect on CP children. These results strongly suggest that neuromuscular control training is needed to improve posture control rather than strengthening exercises. Ballaz et al investigated that restraint-induced exercise therapy and power usage therapy are important for decreasing asymmetric upper limb function on balance and posture but more studies are required with strong evidences. Few studies have provided weak of evidences that supported the use of full and partial body supported treadmill training for the improvement of functional balance in CP. Even at higher doses participants did not show improvement in functional balance but symmetry of weight distribution, endurance, speed and gait patterns were slightly improved[45] more researches are to be conducted to evaluate the definite results.

The trunk lines training is relatively new type of intervention in which participant is enhanced to practice on vibrating platforms, which can improve the sensation, musculoskeletal component in short duration of time[38]. Meanwhile researchers were unable to identify any relationship between the strength and vibrational components of the protocol. Their argument that vibration activates weak and dormant the muscles and reduces the need to strength training and repetition for enhancing functional balance need justifications. In other separate research of vibration therapy supports the concept of stimulation of peripheral sensory receptors and evoke postural responses[46]. For the individuals with cerebral palsy, vibration alone can improve gross motor function and bone density. However strong studies are required to rule-out the effectiveness of vibrational therapy for functional balance in cerebral palsy.

There are some evidences to support the use of reactive balance training to improve the reactive posture among cerebral palsy children but in these studies spontaneous motor control in not achieved[33]. Moreover, when a reaction occurs balance training (Biodex system) combined with expected training (voluntary inclination of stability limit), found to be effective in improvement of voluntary motor control[31]. Meanwhile more studies are required to establish a positive relation.

At last six interventions showed weak evidence. In above paragraphs introduction to the hippotherapy and treadmill training with partial or full weight supported has been made. In all, assessment interventions were mostly noninvasive as NDT is often compared in testing for potential new interventions. Meanwhile it is of great unfortunate that despite the six high level researches, it is hard to lower the level of evidence for such interventions for the various reasons. Firstly, research often lacks

description of the main protocol for intervention of Neurodevelopmental techniques provided, or how was the compliance of the therapist and the patient.

In contrast with other interventions, effectiveness of functional balance and its factors cannot be determined. In some scenarios, the dosage administered is of unspecified or variable form. In other scenarios, individuals in terms of Gross motor function classification, age and gender are different. It is beneficial to address these methodological restrictions in future researches in order to improve better understanding of the relative usefulness of Neurodevelopmental techniques in balance among cerebral palsy population specifically in individuals with severe motor dysfunction. One of the popular relatively new technique is a virtual reality [39,41]. Use of this technique is growing in home and in clinical settings.

The intervention is proposed to affect the motor and sensory components through the voluntary action which are feedback by visual stimulus (screen) and tactile (manual) mode. Three essential conditions for exercise learning supposed to be complete, that is repetition of exercises, active participation of the individual, feedback via the visual and tactile stimulus. Due to lack abundant researches it is harder to conclude about the impact of virtual reality over the balance.

Virtual reality cannot be used as a substitute, while it can be used as an adjunct to other therapies is a suggestion by one of the authors[40]. Use of virtual reality, which include exercises but functional balance is neglected is the reason for the weaker result for improving overall balance of the individuals with cerebral palsy[47]. Current biofeedback[42] and FES [41,42] are the remaining two types of researches which are showing weaker evidence. Both of these show improvements in balance and postural stability but requires more detail reporting of the individuals or larger population must be taken to establish adequate level of guidance for evidence based practice.

CONCLUSION

Exercise protocols and intervention recognized to improve the overall balance; static, dynamic and functional balance is increasing for individual with cerebral palsy. It is concluded with this review that five effective exercise protocols, six that required more investigation and two that are possibly inefficient. Further studies are required to establish (1) reliable tools for assessing outcomes of functional balance; (2) more effective interventions with proper dose guidelines for different types of cerebral palsy; (3) other interventions which had been used in the adult population for the postural control and for the balance like yoga, pilates and tai chi.

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