INSTITUTO POLITÉCNICO DE LISBOA

ESCOLA SUPERIOR DE TECNOLOGIA DA SAÚDE DE LISBOA

DO PHYSICAL THERAPY INTERVENTIONS THAT TARGET POSTURAL CONTROL INFLUENCE FUNCTION AND PARTICIPATION OUTCOMES IN CHILDREN WITH CEREBRAL PALSY? A SYSTEMATIC REVIEW

FILIPA MACHADO MOITA DE DEUS
PROF. LUÍSA PEDRO, PhD – ESCOLA SUPERIOR DE TECNOLOGIA DA SAÚDE DE LISBOA

Mestrado em Fisioterapia, ramo de especialização em Fisioterapia Neurológica

Lisboa, 2020

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Resumo

Introdução: A Paralisia Cerebral (PC) é a incapacidade física mais comum na infância, caracterizada pela disfunção motora, que inclui alterações no controlo postural, assim como em outros domínios, como a função e a participação. O **propósito do estudo** é apresentar uma revisão sistemática de intervenções relacionadas com o controlo postural e reportar a influência das mesmas na função e participação de crianças com PC. **Método:** Foi realizada uma pesquisa em bases de dados – PubMed, PEDro, Sciello, Scopus and Web of Science and ERIC – utilizando os termos "paralisia cerebral", "controlo postural", "função" e "participação". Os critérios de inclusão foram: estudos 1) entre 2010-2020, 2) onde os participantes fossem crianças com PC, 3) de evidência de Oxford nível 2-4, 4) que reportam a eficácia da intervenção em fisioterapia, 5) versões finais e completas, 6) em inglês ou português. **Resultados:** Foram encontrados 888 estudos, 16 dos quais cumprem os critérios de inclusão. Oito tipos de intervenção foram identificadas: treino de marcha, hipoterapia, treino de equilíbrio, produtos de apoio, vibração "*stochstic*", alterações ambientais, intervenção perceptual e motora e NDT. Vários instrumentos de controlo postural e função foram identificados nos estudos. **Discussão e Conclusão:** O tratamento da disfunção de controlo postural, com vista à função, pode incluir treino de equilíbrio com o *Biodex® Balance System*, treino de marcha posterior, e a utilização de palmilhas para crianças com PC nível II da GMFCS. Para os níveis III-V, intervenções como intervenção perceptual e motora e hipoterapia com recurso a um simulador parecem apresentar potencial. No que diz respeito ao tratamento da disfunção de controlo postural, com vista à função e participação ou só participação, não é possível fazer nenhuma sugestão baseada nos resultados do presente estudo. **Palavras-chave:** Paralisia Cerebral, Controlo Postural, Função e Participação

Abstract

Introduction: Cerebral Palsy (CP) is the most common physical disability in childhood, characterized by motor dysfunction, which includes alterations in postural control and in other domains, such as function and participation. The **purpose of this study is** to present a systematic review of interventions that target postural control and report the influence of such interventions in function and participation outcomes for children with CP. **Method:** A journal database search was conducted – PubMed, PEDro, Sciello, Scopus and Web of Science and ERIC –, using the terms "cerebral palsy", "postural control", "function" and "participation". Inclusion criteria was: studies 1) from 2010-2020, 2) where participants were children with CP, 3) of level 2-4 of Oxford Evidence, 4) that reported the effectiveness of Physical Therapy interventions, 5) full final versions, 6) in English or Portuguese. **Results:** 888 studies were screened and sixteen met the inclusion criteria. Eight types of interventions were identified in those studies, namely gait training, hippotherapy, balance training, assistive devices, stochastic vibration, environmental changes, perceptual-motor intervention and NDT. Different instruments were identified in the studies for postural control and function. **Discussion and Conclusion:** Management of postural control dysfunction, with view to function, may include the use of balance training using the Biodex® Balance System, backward gait training and the use of postural insoles for children with CP levels I-II of the GMFCS. For GMFCS levels III-V, interventions such as perceptual-motor therapy and hippotherapy simulator show promise. As for the management of postural control dysfunction, with view to function and participation or just participation, it is not possible to suggest any intervention based on present results. **Key-words:** Cerebral Palsy, Postural Control, Function, Participation.

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Abbreviation List

A

AACPDM – American Academy for Cerebral Palsy and Developmental Medicine

ADLs – Activities of Daily Living

B

BL-CP – Bilateral Spastic Cerebral Palsy

BWT – Backward Walking Training

C

CAPE – Children's Assessment of Participation and Enjoyment

CG – Control Group

COP – Center of Pressure

CP – Cerebral Palsy

F

fPRC – Family of Participation-Related Constructs

FW-tilting – Forward tilting

G

GMFCS – Gross Motor Function Classification System

GMFM – Gross Motor Function Measure

I

ICF – International Classification of Functioning, Disability and Health

ICF-CY – International Classification of Functioning, Disability and Health – Children and Youth

ICP – Independent Cerebral Palsy

IG – Intervention Group

M

MACS – Manual Ability Classification System

MAS – Modified Ashworth Scale

N

NDT – Neurodevelopmental Therapy

O

OCEBM – Oxford Centre for Evidence-Based Medicine

P

PAC – Preferences for Activities of Children

PACMI – Play Assessment of Children with Motor Impairment

PBS – Pediatric Balance Scale

PBWS – Partial Body Weight Support

PBWSTT – Partial Body Weight Supported Treadmill Training

PEDI – Pediatric Evaluation of Disability Inventory

P-M – Perceptual-Motor

PODCI – Pediatric Outcomes Data Collection Instrument

PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analysis

S

SATCo – Segmental Assessment of Trunk Control

SCP – Support Cerebral Palsy

SFA – School Functional Assessment

SMW – Six Minute Walk

SPCE – Surveillance of Cerebral Palsy in Europe

SPCM – Seated Postural Control Measure

STS – Sit to Stand

SV – Stochastic Vibration

T

TIS – Trunk Impairment Scale

TCMS – Trunk Control Measurement Scale

TUG – Timed up and Go

U

US-CP – Unilateral Spastic Cerebral Palsy

W

WeeFIM – Wee Functional Independence Measure

1. Introduction

The present Master's Dissertation will discuss the influence of physical therapy interventions that target postural control in function and participation outcomes in children with cerebral palsy. This Dissertation includes pre-textual elements, as well as textual elements, which are, not only the article itself, but also a brief conclusion and final considerations.

This theme is quite contemporary, seen as children with disabilities and their families seem to, more and more, have the desire to have an active role in their communities. Participation is, therefore, not only an aspect to consider in a child's life, but also a goal to strive for in multiple contexts – including physical therapy.

Interventions, such as those that aim to improve postural control dysfunction, should have functional-related goals and outcomes, seen as focusing mainly on bodily function and structures may not be enough to cause a significant impact on these children's lives. However, when it comes to investigation, studies don't always include the impact of the different types of interventions in functional and participation-related dimensions, therefore leaving a breach between evidence-based and experience-based practice. It's quite intuitive to think that an intervention with a positive result at body function level, has an impact on overall function and on participation. However, when goals for therapy are set, are these factors really taken into consideration? And when assessing types of interventions, do physical therapists privilege the ones that lead to better functional and participation outcomes? The systematic review that follows will help identify interventions that target postural control with a view to function, participation and/or both.

2. Article

Do Physical Therapy Interventions that Target Postural Control Influence Function and Participation Outcomes in Children with Cerebral Palsy? A Systematic Review

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ABSTRACT

Introduction: Cerebral Palsy (CP) is the most common physical disability in childhood, characterized by motor dysfunction, which includes alterations in postural control and in other domains, such as function and participation. The **purpose of this study is** to present a systematic review of interventions that target postural control and report the influence of such interventions in function and participation outcomes for children with CP. **Method:** A journal database search was conducted – PubMed, PEDro, Sciello, Scopus and Web of Science and ERIC –, using the terms "cerebral palsy", "postural control", "function" and "participation". Inclusion criteria was: studies 1) from 2010-2020, 2) where participants were children with CP, 3) of level 2-4 of Oxford Evidence, 4) that reported the effectiveness of Physical Therapy interventions, 5) full final versions, 6) in English or Portuguese. **Results:** 888 studies were screened and sixteen met the inclusion criteria. Eight types of interventions were identified in those studies, namely gait training, hippotherapy, balance training, assistive devices, stochastic vibration, environmental changes, perceptual-motor intervention and NDT. Different instruments were identified in the studies for postural control and function. **Discussion and Conclusion:** Management of postural control dysfunction, with view to function, may include the use of balance training using the Biodex® Balance System, backward gait training and the use of postural insoles for children with CP levels I-II of the GMFCS. For GMFCS levels III-V, interventions such as perceptual-motor therapy and hippotherapy simulator show promise. As for the management of postural control dysfunction, with view to function and participation or just participation, it is not possible to suggest any intervention based on present results. **Key-words:** Cerebral Palsy, Postural Control, Function, Participation.

INTRODUCTION

Graham et al. (2016) state that the term Cerebral Palsy (CP) does not refer "to a specific disease entity, but rather to a group of conditions with variable severity that has certain developmental features in common". The formal definition of this group of conditions was defined in the mid-2000 by an international panel and is as follows: “Cerebral palsy describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication and behavior, by epilepsy and by secondary musculoskeletal problems” (Graham, et al., 2016). CP is the most common physical disability in childhood, with a prevalence of 2.1 cases per 1000 in high-income countries; exact rates in countries of low to middle income are less certain, but appear to be higher, with worse physical disability. CP is a clinical diagnosis based on a combination of clinical and neurological signs (Novak, Morgan, Adde, & et al, 2017).

Motor dysfunction characterizes CP and can be classified according to the movement disorder – spasticity, dyskinesia (which includes dystonia and athetosis), ataxia and hypotonia (Novak, Morgan, Adde, & et al, 2017) –, topographic distribution – unilateral (including monoplegia or hemiplegia) and bilateral (diplegia, triplegia and quadriplegia) (Graham, et al., 2016) – and severity – Gross Motor Function Classification System (GMFCS) levels I to V (Palisano, Rosenbaum, Bartlett, & Livingstone, 2007; Palisano, et al., 1997). The Surveillance of Cerebral Palsy in Europe (SPCE) – a collaboration of cerebral palsy surveys and registers – established the classification of subtypes of CP as follows:

SCPE Classification of CP Subtypes based on the predominant neurological findings		All CP subtypes have in common an abnormal pattern of movement and posture. **Additional features by subtype:**
SPASTIC CP	**Bilateral Spastic (BS-CP)**	Increased tone Pathological reflexes - increased reflexes, e.g. hyperreflexia - pyramidal signs, e.g. Babinski response resulting in abnormal pattern of movement and posture
	Unilateral Spastic (hemiplegia)	
DYSKINETIC CP	**Dystonic**	Involuntary, uncontrolled, recurring, occasionally stereotyped movements, primitive reflexe patterns predominate, muscle tone is varying
	Choreo-athetotic	
ATAXIC CP		Loss of orderly muscular coordination, so that movements are performed with abnormal force, rhythm and accuracy

FIGURE 1: SPCE Classification of CP Subtypes

Novak et al (2017) highlight the importance of early detection of children at risk of having CP and, in the case that they do have it, CP-specific early intervention is recommended as the standard of care to optimize infant neuroplasticity, prevent complications and enhance parent and caregiver well-being. That is the case regarding all aspects of motor development, such as postural control.

Postural Control

Postural control is defined by Lewar, Love & Johnston (2014) as the ability to control the body's position in space for the purposes of stability – where postural stability, or balance, is the ability to maintain and/or regain the center of mass within the base of support and where gravity is the key vector – and orientation – where postural orientation is the ability to attain and maintain an optimal functional relationship between body segments, a task, and the environment, for example, when writing, reaching or looking. A more recent definition, from Araújo et al (2019), states that postural control is "the ability to control the body's center of mass in relation to the person's base of support for maintenance of stability". Further, postural control is regulated by the integration of the somatosensory, vestibular and visual systems, which all develop at different rates throughout childhood – the first being the somatosensory, followed by the other two (Breen, Howell, Stracciolini, Dawkins, & Meehan, 2016). Other than the interactions between sensory information and motor performance in children, postural control also depends on the maturation of the structures involved, as well as on their motor experiences; furthermore in order to maintain postural control, the central nervous system makes different use of sensory information during various phases of motor development (Cardoso de Sá, Boffino, Ramos, & Tanaka, 2018). Dusing (2016) highlights the importance of the postural control system in early development, making it clear to understand that, "while the loss of a single opportunity is unlikely to result in lasting developmental changes, repeated losses of interaction with the environment are likely to have a lasting impact on multiple areas of development" (Dusing, 2016) – which can occur in children with CP, seen as the neuromotor disorders that these children present are influenced by the central role of the deficits they exhibit in postural control (Pavão S. , Santos, Oliveira, & Rocha, 2015). Postural alignment and stability are requirements for voluntary movement, therefore, deficits in this area result in important limitations to activities of daily living (Pavão S. , Santos, Oliveira, & Rocha, 2015) – for which postural control is essential (Oba, Sasagawa, Yamamoto, & Nakazawa, 2015) – and leads to important functional constraints (Pavão S. , Santos, Woollacott, & Rocha, 2013). Pavão S., Santos, Oliveira, & Rocha (2015) highlight that, despite the fact that there have been multiple studies focusing on different aspects related with postural control – such as higher values of postural oscillation in CP, modifications of the muscle recruitment order to maintain stability and higher rates of agonist-antagonist muscle co-activation – there have been far fewer studies assessing postural control during functional tasks or activities. It is also important to consider that extrinsic factors play an important role in postural control adjustments in children with CP, which are constantly challenged in daily routine situations, seen as different sensory environments require different adjustments (Pavão S. , Santos, Woollacott, & Rocha, 2013).

Maintaining a stable posture demands complex interactions between central and peripheral nervous systems as well as the musculoskeletal system, however, these interactions are affected in children with CP, as mentioned above, and therefore postural control mechanisms are altered when compared to healthy peers (Seyyar, Aras, & Aras, 2019). It's a well-known fact that this postural control dysfunction derives from primary brain injury in children with CP, which causes deficits in postural networks – motor networks, which are impacted by deficits such as muscle spasticity, contracture, decreased isometric force production and abnormal timing, and reduced amplitude of muscle recruitment, and perceptual networks, which are impacted by deficits including poor registration and/or perception in visual, tactile, proprioceptive, and vestibular systems (Dewar, Love, & Johnston, 2015). In order to achieve postural control, a complex integration of body systems has to take place in the higher-level neural premotor systems, proprioceptive control and vestibular, visual and auditory senses (Hansen, Hansen, Bencke, Magnusson, & Curtis, 2018) and that may be hindered in children with CP due to partial or complete lack of sensorimotor experience in early childhood, seen as repeated losses of interaction with the environment are likely to have a lasting impact on multiple areas of development, thus leading to a limited range of motor abilities (Dusing, 2016). It was demonstrated that constraints on processing sensory information determine impaired postural control responses in children with CP (Pavão, Silva, Savelsbergh, & Rocha, 2015). Hence, the repetitive nature of an infant's movements and the inability to use sensory information to select efficient postural control strategies while reaching, sitting, or walking, may limit their ability to adapt or change motor patterns in response to changing task demands, therefore contributing to further delays in development, if not identified and treated (Dusing, 2016).

As mentioned above, the problems associated with CP are related to movement and posture and they include alterations in balance and in the alignment that affect sitting position, thus favoring compensatory postures. Due to the motor impairments, namely, those of the trunk and limbs, "there is an inability to generate force to maintain antigravity postural control, thus leading to abnormal posture" and this "affects not only sitting and standing but also the ability to sequence the movements appropriately" (Mendoza, Gómez-Conesa, & Montesinos, 2015). Hansen et al (2017) highlights the importance of understanding the problems associated with trunk control in children with CP, "since trunk control is a prerequisite for free and selective movements of the head and of the upper limbs in independent sitting, as well as for performing everyday activities". There is also "poor selective control of muscle activity and poor regulation of activity in muscle groups in anticipation of postural changes and body movements which result in impaired postural control" (Seyyar, Aras, & Aras, 2019). Therefore, impairments on postural control may occur during static – i.e. while maintaining their posture – and dynamic events or activities – i.e. while changing positions, moving or walking – and are likely to impact negatively on daily activities (Araújo, Starling, Oliveira, Gontijo, & Mancini, 2019) and social participation, thus affecting their quality of life (Pavão, et al., 2019). Accordingly, postural control implies three important mechanisms, regarding the mastering of functional balance and reaching skills: static or steady state balance, active or anticipatory balance, and reactive balance (Hansen, Hansen, Bencke, Magnusson, & Curtis, 2018). Hence, intervention must focus on all such mechanisms, as well as specific skill deficits, while at the same time providing opportunities for regular fun physical activity, thus contributing for potential long term healthy fitness habits for adulthood (Lucas, et al., 2016), independence and quality of life (Seyyar, Aras, & Aras, 2019).

According the systematic review by Dewar, Love & Johnson (2014), there is moderate evidence to support the use of five interventions targeted at postural control: hippotherapy, treadmill training with no-body weight support, trunk-targeted training – which involves exercises aimed at improving trunk muscle strength and control –, reactive balance training – which involves repeated practice of balance recovery, when standing on a support surface that is perturbed without warning in a forward, backward or lateral direction –, and gross motor task training – which involves repetition of simple functional gross motor exercises (e.g. sit-to-stand exercises, step-ups, walking and standing activities, and reaching to limits of stability). Other interventions mentioned in this same study are: functional electrical stimulation – with the aim of improving muscle strength and function –, hippotherapy simulators – to imitate the movement of a horse in an attempt to make hippotherapy accessible in a clinical setting –, neurodevelopmental therapy (NDT), progressive resistance exercise – which involves resisted motion or lifting tasks, with structured increases in training loads, to improve muscle strength –, treadmill training with partial or full body weight support, virtual reality – which involves balance training whilst playing computer games that create a virtual environment using artificial sensory information to simulate real-life experiences or activities –, upper limb interventions – such as constraint-induced movement therapy – and visual biofeedback (Dewar, Love, & Johnston, 2015). To our knowledge, there have been no further systematic reviews about this topic. However, other interventions have been mentioned with some promise, such as adaptive seating (Pham, et al.,

2016) and environmental alterations (Anaby, et al., 2017), for example. Also, combinations of interventions – such as balance-training interventions, along with others like NDT – seem to have positive effects, even though levels of evidence are not high (Araújo, Starling, Oliveira, Gontijo, & Mancini, 2019). Therefore, it is consensual that there is a need for more studies, with higher levels of evidence and stronger methodological descriptions are needed on this topic.

O'Conner et al (2015) define an assessment tool as "any device that collects data about the client that can support the therapist's clinical judgement during the assessment process", which can be a classification system, scale, test or outcome measure. Further, it is highlighted that "within the framework of evidence-based practice, assessment involves the integration of findings from psychometrically robust assessment tools, if and when available, with findings from informal assessments, clinical expertise, and other information sources", meaning that one doesn't substitute the other, but rather completes it. Optimizing health and quality of life outcomes for children CP is an aspiration shared by families, clinicians and researchers, therefore, the use of robust assessment tools in allied health practice is an essential step towards achieving this and needs to be guided by 'best practice' frameworks in health and childhood disability (O'Connor, Kerr, Shields, & Imms, 2016). For postural control, there are multiple tools, namely, the Trunk Control Measurement Scale (TCMS), Trunk Impairment Scale (TIS), Segmental Assessment of Trunk Control (SATCo), and others (Panibatla, Kumar, & Narayan, 2017). Regarding each of them individually, it can be said that:

- The TIS and the TCMS – an extended version of the TIS – assesses quality of static and dynamic trunk control and they have been found to be reliable and valid in children aged 5–19 and 8–15 years, respectively (Pham, et al., 2016);
- Evaluation of trunk control by using the TCMS can provide valuable information for trunk control impairments when compared to the TIS with higher correlation coefficients with functional measures (Seyyar, Aras, & Aras, 2019);
- The TIS is a reliable and valid measure of trunk control for both children and adolescents with CP (Saether, Helbostad, Adde, Jørgensen, & Vik, 2013; Pavão, et al., 2019) and it is able to differentiate levels of trunk control across various levels of motor impairments in CP, thus showing very high concurrent validity with the GMFM sitting dimension (Pavão, et al., 2019);
- The TCMS is reliable and valid in children with spastic CP, giving insight into the strengths and weaknesses of the child's trunk performance (Heyrman, et al., 2011);
- The SATCo test is the only tool developed for CP, which measures reactive sitting balance in addition to static and active sitting balance and it appears to be a reliable and relevant

assessment tool of trunk postural control in children with CP with potential for implementation in clinical practice (Hansen, Hansen, Bencke, Magnusson, & Curtis, 2018).

A key-aspect related to postural control is how it translates into functional outcomes and the overall functionality of the child. The acquisition of sitting postural control has proven to be a predictor of function in children with neurological damage (Seyyar, Aras, & Aras, 2019). Panibatla, Kumar & Narayan (2017) describe functional balance as being impaired in children with CP due to the altered postural control mechanism. They go on to highlight the crucial role of functional balance as one of the components of postural control that helps children execute basic activities of daily, social and recreational activities independently at home, school and in the community, therefore making it easy to understand that any impairment at this level can further affect these children's performance in activities of daily living, in mobility and in participation (Panibatla, Kumar, & Narayan, 2017). Further, children with CP experience difficulties regarding aspects such as controlling their body's position in space, performing anticipatory adjustments for executing functional activities and reacting to unexpected perturbations of balance, with functional consequences related to gait, reach and dealing with rapid changes in load bearing, as well as unexpected disruptions in upright posture – all of these being areas that enable the performance of activities of daily living (Pavão, Nunes, Santos, & Rocha, 2014). Similarly, the development of motor function is very important for skill acquisition and enabling children to participate fully in school and leisure activities, as well as for establishing lifelong physical activity patterns for healthy development into adulthood (Lucas, et al., 2016). Lucas et al (2016) further adds that gross motor skills "are fundamental to childhood development as they underpin functional activities, play and social interaction and in older aged children support complex movement skills required for sport and fitness"; they also "are integral to social, recreational and academic participation and have been linked to healthy self-esteem and cognitive development".

In children with CP, postural control while standing has an important relationship with the level of functionality – for example in activities of daily living – and thus establishes a direct relationship with the level of dependence on a caregiver (Pavão, Nunes, Santos, & Rocha, 2014). Mendoza, Gómez-Conesa & Montesinos (2015) mention that the "ability to acquire the postural control in sitting will influence in the development of other gross motor functions such as standing and walking" and Pavão et al (2018) add that "the greater the level of gross motor impairment, the greater the postural and functional balance deficits found", because "the trunk is a key segment in the organization of postural stabilization and orientation control", and therefore it is likely to influence the performance of gross motor skills. The relationship between functional abilities and sitting postural control was significant in multiple studies (Seyyar, Aras, & Aras, 2019), namely regarding the positive relation between the SATCo and the Pediatric Evaluation of Disability Inventory (PEDI) (Curtis, et al., 2015), as well as the significant relation between the TIS, the TCMS and the Gross Motor Function Measurement scale (GMFM-66) (Pham, et al., 2016) and, finally, between the TCMS and the Pediatric Balance Scale (PBS) (Panibatla, Kumar, & Narayan, 2017). It is possible to say that changes in postural control may determine functional changes, therefore, increasing postural stability should be a goal of physical therapy programs for children with CP, in order to improve their functional and activity levels, as well as their social participation (Pavão, Nunes, Santos, & Rocha, 2014).

Function

Functional ability is the actual or potential capacity of an individual to perform the activities and tasks that can be normally expected. A given function integrates biological, psychological and social domains (Kirch, 2020). The International Classification of Functioning, Disability and Health's (ICF) definition of "functioning" indicates that this "is an umbrella term for body functions, body structures, activities and participation" and it "denotes the positive aspects of the interaction between an individual (with a health condition) and that individual's contextual factors (environmental and personal factors)". The ICF goes on to define "body functions" as "the physiological functions of body systems, including psychological functions". The ICF Child and Youth version (ICF-CY) is an extended version of the ICF and it includes child development as an additional health and health-related component (World Health Organization, 2020).

In the early 2000s, the above mentioned GMFCS was validated for classifying motor abilities and limitations of children with CP (Palisano, et al., 2000), aged 1 to 18, and since then, it has been the reference, as regards to classification systems, to describe gross motor function levels in both research and clinical use (Gray, Ng, & Bartlett, 2010). It includes five levels – Level I represents children with the most independent motor function, and level V represents children with the least – and five age bands. It is based on self-initiated movement, with emphasis on sitting, transfers, and mobility – the focus lies on determining "the level that best reflects the present abilities and limitations of the child and youth in relation to gross motor functions", while also describing important factors such as sitting posture control and the severity of the disability in the daily lives of children with CP. It has been an incredibly useful tool for communication between professionals, for making clinical decisions and also for research (Mendoza, Gómez-

Conesa, & Montesinos, 2015). Another important tool is the Gross Motor Function Measure, which is a standardized observational instrument designed and validated to measure changes in gross motor function over time in children with CP (Lee, Chung, & Lee, 2015). Also, the Manual Ability Classification System (MACS), which is based on the ICF, is designed to classify children with CP according to the extent of their ability to use their hands and manipulate objects in daily activities. The MACS designates five levels of manual function, where the lowest level – level I – corresponds to the ability to easily handle objects and the highest level – level V – indicates severe restrictions in handling objects. It has been found that in school-aged children with CP, the extents of functioning, activity, and participation all depend on the ability of the children to handle and manipulate objects – MACS level – therefore, their functional level affects their level of activity and participation (Lee, Chung, & Lee, 2015). The use of the classification toolset above may help provide immediate benefit for children with CP by ensuring clarity of communication between professionals and accurate assessment of important areas of life for children with CP (O'Connor, Kerr, Shields, & Imms, 2016).

The physical therapy intervention paradigm has shifted from “fixing a deficit”, relative to typical development and movement, to “promoting functional independence and participation and celebrating the children’s spontaneous adaptive movement solutions”, with an “emphasis on family involvement and practical, functional interventions”, as the gold standard of intervention success (Law & Darrah, 2014). Therefore, intervention aims to address deficits at the body function and structure, while minimizing activity limitations, improve functional skills and encourage participation (Morgan, et al., 2016). It’s well established that clinicians must base their treatment decisions on evidence, using interventions that are most likely to produce the greatest improvement in motor outcomes (Lucas, et al., 2016). Thus, efforts have gone towards identifying intervention methods and strategies that promote childhood development, as well as the enhancement of functional independence in various areas of a child’s life (Law & Darrah, 2014), such as movement, self-care and other areas of activities of daily living (ADLs) (James, Ziviani, & Boyd, 2014), play (Chiarello, et al., 2018), school activities (Pereira, et al., 2016), leisure activities (Majnemer, et al., 2008; Majnemer, et al., 2010), quality of life (Park, 2017) and others. A systematic review about the effectiveness of interventions for children with CP revealed that the “green go” approaches that focus on outcomes at the activity level – such as context-focused therapy, goal-directed/functional training, home programs, among others – are more effective (Novak, et al., 2013). It has been described that “more intensive training for a shorter period including practicing in the child’s natural environment may be more effective for learning functional skills", thus supporting the importance of context therapy (Myrhaug, Østensjø, Larun, Odgaard-Jensen, & Jahnsen, 2014). Another author expands on this and highlights the importance of including participation-related domains as well, beyond the activity level – including areas other than ADLs and mobility (Anaby, et al., 2017).

Participation

It is well established that, with the publication of the World Health Organization's ICF, there has been an intensification in the efforts put forth to understand and define "participation", with ever growing interest on this domain due to it being considered the ultimate health outcome, as described by Imms et al (2015). The ICF-CY's description of participation is the "involvement in a life situation" and a participation restriction is defined as 'problems an individual may experience in involvement in life situations' (World Health Organization, 2020). However, that description, for the most part, isn't sufficient, with regards to clarity, when defining outcome goals and developing scales and measures to assess participation outcomes (Imms, et al., 2016) and there is a clear knowledge gap, when it comes to the transactions among ICF-CY domains, thus equally limiting the efforts to design effective interventions (Imms, et al., 2017). The ICF's description has been the focus of some author's commentaries, "questioning its validity and applicability and, in particular, whether or not it captures the essence of the participation construct and reduces inherent ambiguity" (Adair, Ullenhag, Keen, Granlund, & Imms, 2015). Chiarello (2017) highlights that "despite at least two decades of scholarly perspectives and research, embracing participation in pediatric physical therapy" still "appears hindered by an incomplete understanding of the construct, challenges in measurement, limited evidence for interventions, and inadequate service delivery systems restricting novel approaches to care", therefore, "pediatric physical therapy practice is more client centered and goal directed" and there is still "a way to go to ensure that our services support meaningful participation in real-life contexts".

The systematic review by Adair et al (2015) identified a gap in the literature, namely the fact that few high-quality studies have reported favorable participation results after interventions in children with disabilities, thus suggesting that future research should focus on individually tailored programs, aimed primarily at addressing participation outcomes (Adair, Ullenhag, Keen, Granlund, & Imms, 2015). Other studies have highlighted that the tools used to measure outcomes after therapy programs often focus more on gross motor function, to the detriment of other domains, such as participation (O'Connor, Kerr, Shields, & Imms, 2016), and others have emphasized that current knowledge from high-quality studies about effective intervention strategies for improving the outcome of participation is also limited, therefore there is the need to expand the physical therapy scope of practice to include participation-related domains beyond activities of daily living (ADLs) and mobility (Anaby, Law, Majnemer, & Avery, 2018). Participation is, therefore, “a complex multidimensional construct that is discussed and applied as both a process and an outcome; thus, in the context of research, it can be studied as an independent or a dependent variable” and, on an individual level, it can be “seen as a universal outcome – one that is important for both learning and development as well as health and well-being“ (Imms, et al., 2017).

Palisano et al. (2012) defined “optimal participation” as “a subjective, personally determined construct, related to the meaning that is associated with and derived from an individual’s physical, social, and self-engagement in activity and life situations”. What constitutes this concept is defined by the individual and the context for participation, and best quantified by individualized outcome measures. Optimal participation, therefore, “involves the dynamic interaction of determinants (attributes of the child, family, and environment) and dimensions (physical, social, and self-engagement) of participation” (Palisano, et al., 2012). Further studies by Chiarello (2017) conceptualize “optimal participation” as “arising from the dynamic interaction among the child, family, and environmental determinants of participation, and the elements of participation, which we identified as the physical doing, social belonging, and self being, including how a person is thinking and feeling. This “optimal participation” is linked with the predictors of participation, which include child preferences, enjoyment, age, gender, motor and communication abilities, cognition, self-care, adaptive behaviors, associated health conditions, and body structures and functions. This knowledge should help therapists understand how participation varies by child characteristics, even if it may be challenging to apply it to an individual child to guide intervention decisions, due to the influence of family income and ecology, as well as geographic area of residence, policies, attitudes of others, transportation, and availability and accessibility of community programs (Chiarello L. , Excellence in Promoting Participation: Striving for the 10 Cs—Client-Centered Care, Consideration of Complexity, Collaboration, Coaching, Capacity Building, Contextualization, Creativity, Community, Curricular Changes, and Curiosity, 2017). Imms et al (2016) proposed that “if interventions are provided that enhance both attendance in activities and involvement while attending those activities” there will be an improvement regarding the “understanding of outcomes across activity competence, sense of self, and preferences for patterns of participation”, therefore enhancing “long-term health and well-being in children with childhood onset impairment”. Their conceptual analysis of processes and outcomes in childhood disability describes the view that participation can be considered both the entry point – for learning and personal development, thus making it possible to identify the impact of participation experiences on activity performance and body structural and functional changes – and the outcome of intervention, therefore enabling therapists to focus on what matters across the life course. This notion also involves challenging the view that participation restriction can be solved only by addressing environmental barriers, seen as interventions at the level of the ‘body’ or the level of society may be necessary to promote participation in individuals, but neither alone is likely to be sufficient (Imms, et al., 2017). This is ever more important as knowledge increases regarding the impact of low participation patterns of children (Palisano, et al., 2012) and adolescents with physical disabilities on their transition to adulthood (Anaby, Law, Majnemer, & Avery, 2018).

Through the early identification of participation restrictions, therapists can design specific interventions with an impact on different areas of children with CP’s lives – such as the development of motor abilities, advocating for reduction of participation barriers and others – and, therefore help these children grow up to be able to participate more fully as adults in the future (Carey & Long, 2012). For that, outcomes must be measured (Chiarello L. , 2017), regarding the specificity of the participation-domain. However, few intervention studies have focused on participation as a primary outcome measure (Adair, Ullenhag, Keen, Granlund, & Imms, 2015). One literature review identified twenty instruments meant to measure activity and participation; however, this review reported that none of them measured all of the dimensions in all life areas, therefore revealing a gap (Phillips, Olds, Boshof, & Lane, 2013). A more recent systematic review identified 118 published measures used to quantify different aspects of participation for disabled children – the most frequent of which were the Children’s Assessment of Participation and Enjoyment (CAPE) and its companion measure the Preferences for Activities of Children (PAC), the Assessment of Life Habits, the Child and Family Follow-Up Survey which included the Child and Adolescent Scale of Participation and SFA (Adair, et al., 2018). The School Functional Assessment (SFA) is composed of three parts – participation, task supports and activity performance – and it provides separate measures of the child/student’s level of participation in school settings, performance of functional activities, and associated support components. It measures the child/student’s capacity for function but also to assess the community performance of that function, which is important because a child’s motor capability may be different in the social setting when compared to the clinical setting

(Rabinovich, Patel, Gates, & Otsuka, 2015). Other measures have been reported such as the Miller Function & Participation Scales, the Children Helping Out: Responsibilities, Expectations, and Supports, the Canadian Occupational Performance Measure and Goal Attainment Scaling – these last three, however, aren't specific for participation measurement (Carey & Long, 2012). Tools such as the CAPE, the Participation and Environment Measure for Children and the Youth and the Child Engagement in Daily Life recognize that participation is multidimensional (Chiarello L. , 2017). There is growing evidence that participation is an evolving concept and, therefore, perhaps measures may need to be updated as our understanding changes (Adair, et al., 2018).

Imms et al (2016) brings out that therapeutic interventions that address issues within the individual's 'body structure and function' through 'treatments' to promote the development of functional skills, for example, motor performance or working memory, will lead to functioning (i.e. reduced impairment of illness, or increased activity capacity) and that will, in turn, lead to more functional everyday skills and increased participation. However, currently, there is little evidence that single interventions aimed at changing specific physiological or psychological functions at the level of body structure and function will necessarily transfer to global changes in participation. A primary focus on participation may achieve a "model of individual functioning that unites aspects of functioning at the level of body structure/function and activity with functioning in everyday life" (Imms, et al., 2017). Anaby et al. (2016) also highlights that, "while body functions and structures have been readily addressed in practice for many years, it is now widely recognized that participation is also key to a child's development, health, and well-being, and is one of the most important outcomes of rehabilitation intervention for children with cerebral palsy". This is all the more important as it is more widely recognized that the participation of children with disabilities is more restricted than same-aged typically developing peers. Interestingly, clinicians tend to focus more on the ICF's traditional components of "body functions and structure", such as muscle tone and motor control, and "activity", such as, gross-motor skills or gait functioning, rather than on "participation" (e.g., socialization, recreation) (Anaby, et al., 2017).

Seen as "participation" is a complex multidimensional construct, a family of participation and participation-related constructs (fPRC) was created from a content analysis of research notions about participation (Imms, et al., 2017) and each term was defined, so as to consistently "promote effective selection/development of measures for use in research and practice that aims to enhance participation outcomes" (Imms, et al., 2016). These constructs, and the framework, can be used to describe the relationships among important within-person factors that are influenced by past participation, and that influence future participation (Imms, et al., 2017). Imms et al (2016) goes on to mention that "the fPRC framework, addressing issues at the level of the individual in context, expands the activity and participation domain of the ICF-CY by further detailing related constructs within an overarching environmental framework". Within the fPRC, participation has two essential components: attendance, defined as 'being there' and measured as frequency of attending, and/or the range or diversity of activities; and involvement, the experience of participation while attending. Involvement might include elements of engagement, motivation, persistence, social connection, and level of affect. Attendance is a necessary but not sufficient requirement for involvement, hence involvement is embedded within the attendance dimension (Imms, et al., 2017). There are, therefore, intrinsic – activity competence (the ability to execute the activity being undertaken according to an expected standard), sense of self (intra-personal outcomes of participation related to confidence, satisfaction and self-esteem), preferences (the opportunity to choose and to be able to undertake activities that are meaningful or valued) – and extrinsic factors and concepts related to participation – availability (objective provision of activities or services), accessibility (ability or perceived ability to access the activity or situation), affordability (financial, time, energy, and other resource constraints to attending), accommodability (the ability of the situation to be adapted or modified) and acceptability (the person's acceptance of the situation, and other people's acceptance of the individual in the activity setting) (Imms, et al., 2016).

PURPOSE OF THE PRESENT STUDY

Keeping this in mind, the purpose of this paper is to present a systematic review of interventions for children (ages 0-18) with CP that target postural control and that report the influence of such interventions in function and participation outcomes. The PICO question that results is, therefore: in children with CP (population), do physical therapy interventions that target postural control (intervention and comparison) influence function and participation outcomes (outcome)? Further, the research question is: which physical therapy interventions that target postural control and that have an impact on function and participation are reported in literature?

METHOD

PROTOCOL, SEARCH STRATEGY AND INFORMATION SOURCES

This systematic review was conducted according to principles of the American Academy for Cerebral Palsy and Developmental Medicine Methodology to Develop Systematic Reviews of Treatment Interventions – Revision 1.2 of 2008 (AACPDM, 2020), and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Pati & Lorusso, 2018; Stewart, et al., 2015).

The structured database search was undertaken between January 27th and February 3rd 2020, using databases covering, not only the field of science and health – PubMed, PEDro, Sciello, Scopus and Web of Science –, but also the field of education – ERIC. The search included terms related to the population of children with CP, therapeutic interventions that target postural control and the concepts of function and participation. These terms were developed on based on the theoretical framework of the present study. The exact terms used in the search engines were: cerebral palsy, postural control, function and participation. These terms were used together and separately in the following combinations in all the above mentioned databases: Combination A – "cerebral palsy" AND "postural control" AND "function", Combination B – "cerebral palsy" AND "postural control" AND "participation", Combination C – "cerebral palsy" AND "postural control" AND "function" AND "participation". There was a need to divide the search this way, due to the fact that there was some difficulty in finding articles that contained both function and participation measures, as will be discussed further in the present study. As a result, specific conclusions relative to each combination of terms could not be drawn independently, if this division didn't exist.

ELIGIBILITY CRITERIA – INCLUSION AND EXCLUSION

The inclusion criteria for the present study was: 1) studies from 2010 through to 2020, 2) studies where the participants were children (0-18 years old) with Cerebral Palsy, 3) studies of level 2 of Oxford Evidence were included – seen as level 1 evidence did not exist on the topic –, as well as levels 3 and 4, if there weren't any level 2 studies on the topic or if the information was particularly relevant for the present study, being the next best available highest level of evidence (OCEBM Levels of Evidence Working Group, 2020), 4) studies reported physical therapy interventions for improving postural control, using at least one outcome measure of postural control – postural stability (static or dynamic balance), postural orientation (e.g. postural alignment) or a standardized test, for example –, as well as at least one quantitative outcome measure for function and/or – depending on the search combination – quantitative or qualitative outcome measure or participation, 5) full final versions of the papers, and 6) articles in English or Portuguese. Note that all inclusion criteria was applied to the product of all the database searches, with the only specific adjustment of the abovementioned item 4, where: for Combination A, there had to be at least one outcome measure of postural control, as well as at least one for function (quantitative); for Combination B, there had to be at least one outcome measure of postural control, as well as at least one for participation (which could be quantitative or qualitative); for Combination C, there had to be at least one outcome measure of postural control, as well as at least one for function (quantitative) and another one for participation (quantitative or qualitative).

The exclusion criteria for the present study was: 1) studies prior to 2010, 2) studies that included other diagnosis, not just CP, 3) studies that included adults (>18 years old), 4) studies about other Therapies, such as Occupational Therapy, 5) articles that do not include outcome measures for postural control and/or, respectively, for Combination A, B and C, that do not report at least one outcome measure for function, participation and function and participation, 6) papers without final and full versions, reviewed by peers, 7) articles in languages other than English or Portuguese, 8) articles without a specific intervention, i.e., assessment only, and 9) articles that provided low levels of evidence, including articles with significant methodological lapses.

STUDY/ARTICLE SELECTION AND QUALITY RATINGS

All steps in the selection and extraction processes regarding quality synthesis (i.e., the study selection, data extraction, and risk of bias evaluation) were assessed by both reviewers. Any disagreement between the reviewers in these processes was resolved through discussions between the two and it was determined that the main author had the final say in the decision. The titles and abstracts of all retrieved references were screened and the full texts of relevant publications were reviewed and included if they met the inclusion criteria (Stewart, et al., 2015; Pati & Lorusso, 2018).

Firstly, studies were rated using the Oxford Centre for Evidence-Based Medicine (OCEBM) 2011 Levels of Evidence for treatment benefits, which includes: level 1, a systematic review of randomized trials or n-of-1 trials; level 2, a randomized trial or observational study with dramatic effect; level 3, a non-randomized controlled cohort/follow-up study; level 4, a case series, case–

control study, or a historically controlled study; and level 5, mechanism based reasoning. Studies were accepted from levels 1 to 4, as highlighted in the inclusion criteria, in order to include the best available highest level of evidence (OCEBM Levels of Evidence Working Group, 2020).

Then, studies were assessed using the American Academy for Cerebral Palsy and Developmental Medicine (AACPDM) assessment tool by both authors independently, which rates group studies as Strong ('yes' score on 6-7 of the seven questions), Moderate (score 4-5 of the seven questions) or Weak (score <3 of the seven questions) (AACPDM, 2020).

DATA COLLECTION PROCESS

DATA EXTRACTION AND QUALITY ASSESSMENT

The data from the included studies was extracted using a data extraction form created – developed, tested and modified by the main author and verified by the other one – for this study, which included information on the study population, design, interventions, outcome measures and conclusions. Authors of included studies were not contacted for missing data. Quality assessment was conducted through the AACPDM tool and the results of that process are in the Appendix.

DATA SYNTHESIS AND ANALYSIS

A descriptive approach was chosen over a meta-analysis, due to the heterogeneity in study design, data collection methods and reporting of study outcomes in the different articles included. Data is, this way, synthetized according to study quality, participant details, intervention description, outcome measures, results and conclusions.

In some studies, assumptions and simplifications may be made, as is mentioned in the PRISMA instrument, and those must be disclosed for the purpose of total clarity and transparency (Stewart, et al., 2015). Therefore, in this study it can be said that assumptions were made specifically with regard to assessment of gait in one article, which includes forward and backward walking as part of the treatment without including specific, objective clinical gait analysis. The assumption made has to do with the homogeneity of the sample – the knowledge of their GMFCS level and type of CP, mainly –, that allows for the inference that gait characteristics were observed, even though they weren't described. Also, globally, simplification was made in order to separate articles selected from combination A, B and C, mentioned above, so that conclusions could be drawn from each combination individually and compared. Though unusual, it was the method adopted in order to differentiate between the different combinations, thus reducing risk of bias. Another global simplification was used in order to accept "balance" and "gait" analysis as part of "postural control", on the basis of abovementioned theoretical review. Therefore, articles with objective measures of balance and clinical gait analysis were accepted and information relative to these terms was treated under the same criteria as "postural control". Simplifications were made specifically as to the interpretation of "dynamic limits of stability in the standing position", accepting that as a measure of function, in addition to balance, in the context of one study – this did not apply to any other study. No other assumptions or simplifications were made.

RISK OF BIAS – INDIVIDUAL STUDIES

Risk of bias must be discussed in terms of how the risk was assessed for each individual article and how it will be used in the data synthesis of the present study (Pati & Lorusso, 2018). Individual studies were assessed as to risk of bias with the AACPDM tool, where the last question mentions: "*Considering the potential within the study design, were appropriate methods for controlling confounding variables and limiting potential biases used*?" With this in mind, it is possible to say that three out of the 10 studies with OCEBM level 2 responded negatively to the question above and out of the remaining six studies with OCEBM levels 3-4, two responded negatively. This will be further discussed in the Results.

RESULTS

STUDY SELECTION

Using the search strategy, a total of 888 studies were screened. Specifically according to each combination, the number of studies screened for combination A was 645, 136 for combination B and 107 for combination C. The first stage included exclusion of articles without the "full text" option available, the second stage included exclusion of duplicates, followed by the third phase, in which articles were excluded based on title and abstract analysis. Following that, there was a thorough examination of the content of each article, where those that did not follow inclusion criteria were excluded (Stewart, et al., 2015). There were 16 articles that met the inclusion criteria – 10 RCTs and six studies of other types – as evidenced in the following flowchart (figure 2).

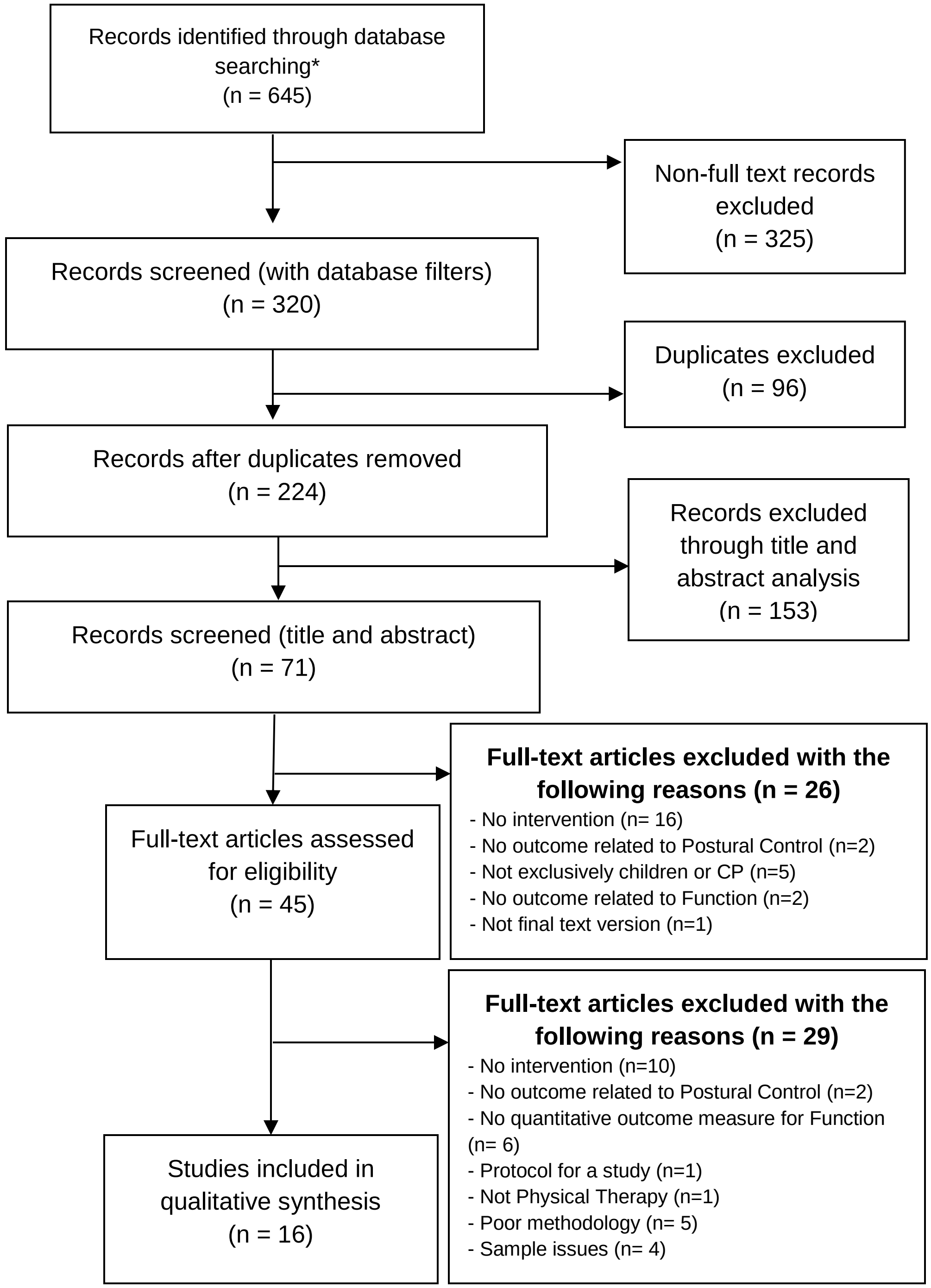

FIGURE 2: PRISMA Flowchart 1 – combination A

*Not all database searches allowed for filters to be applied, so this first step includes all articles

STUDY CHARACTERISTICS

- PARTICIPANTS AND SETTINGS

Participants from the all the studies included in the present study had CP, which is, in itself, a heterogeneous condition that includes children with different functional levels and abilities (GMFCS and MACS levels I to V), different motor subtypes (spastic, dyskinetic, dystonic, ataxic or not classifiable) and different topographic distribution (unilateral/hemiplegia, bilateral/diplegia, bilateral/quadriplegia). All these different characteristics were accepted and the different demographic descriptions of participants are shown in Table 1 and 2. With regard to GMFCS levels, 10 studies included participants classified as level I, 13 studies included participants classified as level II, 11 studies included participants classified as level III, seven studies included participants classified as level IV, two studies included participants classified as level V and one study used the term “moderate to severe”. The higher-quality studies tend to limit participants to one or two different GMFCS levels, to enable better interpretation of treatment effects taking into account the severity of the disability – this happens with some moderate-quality studies too. Most studies’ participants had spastic CP, but some also had dyskinetic, dystonic, ataxic or non-classifiable CP, and finally, two studies do not mention CP type at all. Most participants had CP, except in one study where the control group was composed of typically developed children. The number of participants for the studies ranged from 15 to 146 and the number of participants in each group (intervention and control) was balanced in every case – maximum of 2 participants more in one group than the other – except for one study where there was a difference of 7 participants from one group to the other. There was a trend for more males than females in most of the studies and the age of the participants ranged from 1 to 15 years of age. Interventions took place in a clinical, context, lab or mixed (clinical and context) setting. As to frequency, most interventions took place between two to three times a week (seven studies), followed by 4-5 times a week (four studies) and the rest were daily interventions, once a week or the study of the immediate effects of an intervention. Interventions lasted between four weeks to six months – four weeks (one study), six weeks (one study), eight weeks (two studies), ten weeks (two studies), twelve weeks (six studies), six months (one study) and the immediate effect of an intervention (three studies) – and only two studies had a follow-up period to examine effects after the intervention was withdrawn.

TABLE 1 – Summary of studies RCT (continued)

Reference	Design Level of Evidence Method Quality	Participant Details	Description & Frequency - Intervention Group - Control Group	Assessment and Outcome Measures	Results & Conclusions
(Johnston, et al., 2011)	RCT OCEBM II AACPDM M (4/7)	**TOTAL n=26** **Intervention Group (IG) (n=14)** **Gender:** 7 males, 7 females **Age gap:** 6-13 years (y) **Diagnosis:** spastic CP **GMFCS levels** II, III and IV **Control Group (CG) (n=12)** **Gender:** 7 males, 5 females **Age gap:** 6-13y **Diagnosis:** spastic CP **GMFCS levels** II, III and IV	**Type of Intervention:** Gait training – Partial Body Weight Supported Treadmill Training (PBWSTT) **Intervention Group (IG)** Supported speed treadmill training exercise program: the intervention's goal is to encourage faster walking speeds while walking on the treadmill with partial bodyweight support. **Control Group (CG)** Exercise intervention group: exercise program for spasticity, strength, motor control, gait speed, gross motor skills, and physical function. **Frequency (both groups)**: Induction period (2x/day for 2 weeks) followed by intervention period – 30 minutes (min), 5 days/week for 10 weeks **Setting:** Clinical + Context	Spasticity, Motor control and Strength – KinCom dynamometer Three-dimensional Gait analysis Gross Motor Skills –GMFM, dimensions A to E Physical function – Pediatric Outcomes Data Collection Instrument (PODCI)	IG did not have better outcomes in strength, spasticity or motor control, but showed gains in PODCI global scores and were able to maintain gains in some variables – gait speed and PODCI – once the intervention was withdrawn. Both groups showed important changes in functional measures – gait speed and PODCI, but not GMFM.
(Herrero, et al., 2012)	RCT OCEBM II AACPDM M (4/7)	**TOTAL n=38** **IG (n=19)** **Gender:** 14 males, 5 females **Age gap:** 8-11y **Diagnosis:** CP **GMFCS levels** I, II, III, IV and V **CG (n=19)** **Gender:** 10 males, 9 females **Age gap:** 7-10y **Diagnosis:** CP **GMFCS levels** I, II, III, IV and V	**Type of Intervention:** Hippotherapy – simulator **IG** Simulator ON: sitting on the hippotherapy simulator with active extension of the trunk while the simulator was on "workout" mode. **CG** Simulator OFF: sitting on the hippotherapy simulator with active extension of the trunk with the simulator off. **Frequency (both groups):** Treatment was provided 1x/week (15min) for 10 weeks **Setting:** Clinical	Gross Motor Skills – GMFM-66 Sitting Balance – GMFM-66 (dimension B) and the Sitting Assessment Scale	Hippotherapy with a simulator, in addition to physical therapy, can improve sitting balance – bigger benefits for children who have higher levels of disability and smaller benefits for those with higher levels of ability. Hippotherapy with a simulator did not lead to a change in the overall function of children classified as level V of the GMFCS.
(El-Shamy & El Kafy, 2014)	RCT OCEBM II AACPDM S (6/7)	**TOTAL n=30** **IG (n=14)** **Gender:** 8 males and 6 females **Age gap:** 10-12y **Diagnosis:** spastic diplegic CP **GMFCS levels** I and II **CG (n=16)** **Gender:** 12 males and 4 famles **Age gap:** 10-12y **Diagnosis:** spastic diplegic CP **GMFCS levels** I and II	**Type of Intervention:** Balance training – Biodex® balace system **IG** Traditional neuro-developmental physical therapy exercise program + Balance training on the Biodex balance system **CG** Traditional neuro-developmental physical therapy exercise program **Frequency (both groups):** Treatment provided 30 min/day, 3 days/week for 3 successive months. **Setting:** Clinical	Pediatric Balance Scale (PBS) Biodex balance system Dynamic limits of stability (standing position) Spasticity in involved lower extremity – Modified Ashworth Scale (MAS)	Using different programs of the Biodex stability system for reactive balance control training is very effective in improving the postural balance control and in reducing the risk of fall in children with spastic diplegic CP.

TABLE 1 – Summary of studies RCT (continued)

Reference	Design Level of Evidence Method Quality	Participant Details	Description & Frequency - Intervention Group - Control Group	Assessment and Outcome Measures	Results & Conclusions
(El-Basatiny & Abdelaziem, 2015)	RCT OCEBM II AACPDM S (6/7)	**TOTAL n=30** **IG (n=15)** **Gender:** 7 males and 8 females **Age gap:** 10-13y **Diagnosis:** spastic hemiparetic CP **GMFCS levels** I and II **CG (n=15)** **Gender:** 9 males and 6 females **Age gap:** 11-13y **Diagnosis:** spastic hemiparetic CP **GMFCS levels** I and II	**Type of Intervention:** Backward walking training (BWT) **IG** Traditional physical therapy program on postural control + BWT **Frequency:** 60 minutes, 3 sessions/week for 3 successive months + 25 min/day of BWT **CG** Traditional physical therapy program on postural control **Frequency (both groups):** 60min, 3x/week for 3 successive months **Setting:** Clinical	Forward and Backward Gait observation Balance – Tilt board balance test and Biodex balance system Spasticity – MAS	Additional backward walking training to traditional physical therapy program yields improvement in postural stability indices in children with spastic hemiparetic CP. Improvement in postural balance control and stability in all participating children immediately post-treatment – higher improvement in IG.
(Christovão, et al., 2015)	RCT OCEBM II AACPDM S (7/7)	**TOTAL n=20** **IG (n=10)** **Gender:** 2 males and 8 females **Age gap:** 4-9y **Diagnosis:** spastic diplegic CP **GMFCS levels** I and II **CG (n=10)** **Gender:** 3 males and 7 females **Age gap:** 5-9y **Diagnosis:** spastic diplegic CP **GMFCS levels** I and II	**Type of Intervention:** Assistive devices – insoles **IG** Postural insoles – with corrective elements **CG** Placebo insoles – without corrective elements **Frequency (both groups):** daily usage – assessed at onset (immediate effect), after 3 months of usage and one month after suspending usage **Setting:** Lab	Balance – Berg Balance Scale and the oscillations from the center of pressure Functional mobility – Timed Up-and-Go (TUG) Test Assessment of physical fitness and functional mobility – Six-Minute Walk (SMW) Test Gross Motor Skills – GMFM-88	Postural insoles led to an improvement in static balance and mobility, as well as in performance on the TUG Test. Insoles constitute an important tool for improving functional balance – they cause a change in sensorial afference, stimulating a postural reaction that favors a better biomechanical alignment of the body and permits more efficient function, especially with regard to balance.
(Tarakci, Huseyinsinoglu, Tarakci, & Ozdinçler, 2016)	RCT OCEBM II AACPDM M (4/7)	**TOTAL n=30** **IG (n=15)** **Gender:** 10 males and 5 females **Age gap:** 7-13y **Diagnosis:** CP – Hemiplegic , Diplegic and Dyskinetic **GMFCS levels** I and II **CG (n=15)** **Gender:** 9 males and 6 females **Age gap:** 7-13y **Diagnosis:** CP – Hemiplegic, Diplegic and Dyskinetic **GMFCS levels** I, II and III	**Type of Intervention:** Balance – New technologies (Wii®) **IG** Wii-Fit balance based video games + Neurodevelopment Treatment (NDT) **CG** Balance training group + NDT (same as IG) **Frequency (both groups):** 2 days/week (50 min/session) for a total of 12 weeks **Setting:** Clinical	Dynamic standing balance – Functional Reach Test Muscle strength – Sit-to-Stand (STS) Test Functional mobility – TUG Test Nintendo Wii Fit balance, age and game scores Functional tests and measures – 10-meter walk test, 10-step climbing test and Wee-Functional Independence Measure (Wee FIM)	Wii-Fit balance-based video games are important components of CP rehabilitation – it provides satisfaction, motivation and fun. Improvement on balance parameters and independence level in activities of daily life. Wee FIM Transfers subscores did not change statistically significantly after treatment in both groups. The changes in all other primary and secondary outcome measures were significant, in favor of the IG.

TABLE 1 – Summary of studies RCT (continued)

Reference	Design Level of Evidence Method Quality	Participant Details	Description & Frequency - Intervention Group - Control Group	Assessment and Outcome Measures	Results & Conclusions
(Curtis, et al., 2018)	RCT OCEBM II AACPDM S (7/7)	**TOTAL n=28** **IG (n=14)** **Gender:** 11 males and 3 females **Age gap:** 2-15y **Diagnosis:** CP – Spastic and Dyskinetic **GMFCS levels** III, IV and V **CG (n=14)** **Gender:** 7 males and 7 females **Age gap:** 2-15y **Diagnosis:** CP – Spastic and Dyskinetic **GMFCS levels** III, IV and V	**Type of Intervention:** Balance training – segmental training **IG** Segmental training (targeted training): training head and trunk control **Frequency:** Up to 30min, 5 days a week for a period of 6 months. **CG** Usual physiotherapy (Not standardized, but reflecting clinical practice) **Frequency:** Unclear **Setting:** Context	Gross Motor Skills – GMFM-66-Item Set (GMFM-66-IS) Function – PEDI Postural Control – SATCo and Postural sway	Segmental training was not superior to conventional physiotherapy in improving gross motor function, functional mobility or trunk control. Improvements in head and trunk sway were greater in the segmental training group, but not at follow-up.
(Kyvelidou, Harbourne, Haworth, Schmid, & Stergiou, 2018)	RCT OCEBM II AACPDM M (4/7)	**TOTAL n=30** **IG (n=16)** **Gender:** no data **Age gap:** 2-6y **Diagnosis:** CP – Spastic Bilateral, Dyskinetic, Dystonic and Non-classifiable **GMFCS levels** II/III and III/IV **CG (n=14)** **Gender:** no data **Age gap:** 2-6y **Diagnosis:** CP – Spastic Bilateral, Dyskinetic and Dystonic **GMFCS levels** II/III and III/IV	**Type of Intervention:** Stochastic vibration (SV) **IG** Standard of care (which, on average, includes consultative physical therapy 1/week) + Perceptual-motor (P-M) therapy + SV to the seating surface during therapy **CG** In addition to the standard of care the children received (same as IG), they benefited from: Perceptual-motor therapy (same as IG) **Frequency:** 60min of physical therapy, 2x/week for twelve weeks **Setting:** Lab	Center of pressure (COP) assessment Sitting subsection of the GMFM-88	Both groups made similar progress in sitting stages and the variability of the postural sway. SV stimulus did not advance the development of sitting postural control. GMFM scores were significantly greater than baseline in both groups – positive changes as a result of the P-M therapy but not due to the addition of SV. Significant changes noted in sitting scores and single-subject analysis support the use of the PMT.
(Wallard, Dietrich, Kerlirzin, & Bredin, 2018)	RCT OCEBM II AACPDM M (5/7)	**TOTAL n=30** **IG (n=14)** **Gender:** 8 males and 6 females **Age gap:** 8-10y **Diagnosis:** bilateral spastic CP **GMFCS level** II **CG (n=16)** **Gender:** 7 males and 9 females **Age gap:** 8-10y **Diagnosis:** bilateral spastic CP **GMFCS level** II	**Type of Intervention:** Gait training – PBWSTT **IG** Lokomat® Pediatric – Initial body-weight support was 70%, and was then gradually decreased to 40% over the sessions, according to the participant's functional capacity **Frequency:** Twenty sessions – 40 min – spread over a period of four weeks **CG** Physical or occupational therapy with a physiotherapist **Frequency:** Daily – not clear **Setting:** Lab	Clinical gait analysis Gross Motor Skills – GMFM-66 (dimensions D and E)	Robotic gait rehabilitation is useful mainly regarding balance control in gait – beneficial effect on recovery and improvement of postural and locomotor functions. Children improve their gait – reorganization of gait pattern –, which becomes quantitatively more harmonious, and children are able to walk greater distances. Task-specific improvements in gait parameters – improvement in standing was equally as good as walking – suggesting an additional effect on the stabilization of posture.

TABLE 1 – Summary of studies RCT

Reference	Design Level of Evidence Method Quality	Participant Details	Description & Frequency - Intervention Group - Control Group	Assessment and Outcome Measures	Results & Conclusions
(Pin & Butler, 2019)	RCT OCEBM II AACPDM S (6/7)	**TOTAL n=18** **IG (n=9)** **Gender:** 5 males and 4 females **Age gap:** 6-11y **Diagnosis:** Bilateral spastic CP **GMFCS levels** III and IV **CG (n=9)** **Gender:** 6 males and 3 females **Age gap:** 7-11y **Diagnosis:** Bilateral spastic CP **GMFCS levels** III and IV	**Type of Intervention:** Balance training – interactive computer play **IG** Usual physiotherapy program + trunk control training using the interactive computer play in sitting (TYMO® – commercial portable force plate is specifically designed to assess and treat postural control and 'suitable for the therapy of neurological and orthopedic patients of all ages') **Frequency:** 4x/week, 20 min/session for six weeks. **CG** Usual physiotherapy program (same as IG) **Frequency:** Not clear **Setting:** Context	Balance – Pediatric Reach Test Gross motor function – GMFM–66 Sub-maximal exercise ability – 2-Minute Walk Test	Feasible and safe for children with moderate CP in special school settings. Children in both groups generally improved their sitting balance and functional gross motor skills. There was no added benefit – in improving sitting balance and gross motor function – found from the additional six-week interactive computer play training.

TABLE 2 – Summary of studies Non-RCT (continued)

Reference	Design Level of Evidence Method Quality	Participant Details	Description & Frequency - Intervention Group - Control Group	Assessment and Outcome Measures	Results & Conclusions
(Lazzeri de Medeiros, et al., 2015)	Case Control Study OCEBM IV AACPDM W (3/7)	**TOTAL n=28** **IG (n=14)** **Gender:** no data **Age gap:** 6-12y **Diagnosis:** CP – diplegic and quadriparetic **GMFCS level** I – Independent CP (ICP) subgroup – and levels II and III – Support CP (SCP) subgroup **CG (n=14)** **Gender:** no data, but gender matched group **Age gap:** 6-10y **Diagnosis:** none – typically developing children	**Type of Intervention:** Environmental changes – Seat height and foot placement STS task was demonstrated and participants were given time to practice it. Participants were positioned on the force plate and instructed, by verbal command, to go from sitting to standing with their arms folded across their chest to prevent them from using their arms or hands during task execution - CG and ICP groups performed the task without aid, while those SCP did so with the least possible manual support from the evaluator. Bench/seat height was adjusted in random order (low to high or high to low). Two ways were used to position the feet: (1) the child's preferred foot position, where the individual stood without being corrected by the evaluator; and (2) an optimized foot position, where by the feet were placed 10 cm behind a line drawn vertically from the center of the child's knee joint. **Frequency (both groups):** Immediate effect **Setting:** Lab	Balance – PBS Motor function –GMFCS Kinematic (with a camera) and kinetic (COP displacement) data of STS task at two different seat heights and foot placement positions	SCP has less COP – this does not mean that this group had a better postural control. ICP exhibited greater COP in mediolateral direction oscillations than controls. PBS score among SCP was lower than in either controls or ICP, indicating less balance relative to both groups; even though SCP exhibited significantly less balance, they had smaller COPAP and COPML oscillation/ displacement than the other two groups, what means the better postural control during STS. The time required to complete the STS task was longer in children with CP versus CG; seat height did not influence how long the STS task took. Seat height and foot placement do not influence postural control in children with CP in terms of kinetic parameters; it does influence kinematic variables – highlighting the importance of encouraging posterior positioning of the feet and increasing displacement of the trunk. When necessary, support should be provided while children are being trained for this task, as it may provide benefits like increased muscle strength of lower limb extensors and improved selective motor control.

TABLE 2 – Summary of studies Non-RCT (continued)

Reference	Design Level of Evidence Method Quality	Participant Details	Description & Frequency - Intervention Group - Control Group	Assessment and Outcome Measures	Results & Conclusions
(Ryalls, et al., 2016)	Non-Randomized Controled Trial OCEBM III AACPDM M (4/7)	**TOTAL n=30** **Gender:** 19 males, 11 females **Age gap:** 1-6y **Diagnosis:** CP **GMFCS levels** – not disclosed. Article mentions moderate to severe CP	**Type of Intervention:** Perceptual-motor Environmental forces are used during self-initiated goal-directed movements to change function and postural control. Overall, activities were aimed at teaching the child to attend to significant environmental information. The therapist presented an environmental modification requiring a small movement or postural challenge to the child, and waited for the child to solve the problem, giving very light cues or assistance. The focus was on helping the child utilize forces to obtain a functional goal through problem solving. **Frequency:** 45 min of physical therapy intervention – perceptual motor techniques – 2x/week for 12 weeks **Setting:** Lab (simulating a living room)	Gross motor function – GMFM Play Assessment of Children with Motor Impairment (PACMI) Assessment of beginning sitting skills	Emerging play-behavior can be reliably measured in motor-delayed children; interventions that improve a child's ability to play may be important to improving function. An ecological intervention can significantly improve sitting ability – and consequently in simple pretend play – in children with moderate to severe CP. Documenting a link between sitting and play in motor-delayed children demonstrates that such links can exist independent of typical chronological development. GMFM sitting scores of all the children that received the perceptual motor intervention improved. The sitting intervention did not directly target play, and yet, overall, children both improved at sitting and most of them showed greater ability to manipulate the toys after the intervention.
(Angsupaisal, et al., 2017)	Exploratory Study OCEBM IV AACPDM M (4/7)	**TOTAL n=19** **Group Unilateral Spastic CP (US-CP) (n=10)** **Gender:** 5 males, 5 females **Age gap:** 6–12y **Diagnosis:** spastic CP **GMFCS levels** I, II and III **Group Bilateral Spastic CP (BS-CP) ((n=9)** **Gender:** 2 male, 7 female **Age gap:** 6–12y **Diagnosis:** spastic CP **GMFCS levels** I, II and III	**Type of Intervention:** Environmental changes – seat tilting Horizontal seating condition: sitting on a smooth surface mounted on a table, without additional support. The seat surface could be tilted to a 15° FW-tilt. For the conditions with foot-support, a firm box with a horizontal surface with an adjustable height was placed below the child's feet. The height of the foot support surface was adjusted to the size of the child's (lower) legs, allowing full weight bearing by the feet while sitting. Simple reaching task during which the child reached at its own self-paced speed at arm-length distance. **Frequency (both groups):** Immediate effect **Setting:** Lab	Assessment in four seating conditions: horizontal seat surface without (a) and with (b) foot-support, and 15° FW-tilted seat surface without (c) and with (d) foot-support Motor Function – GMFM-66 Spasticity – Modified Tardieu Kinematic analysisof head sway and reaching (PedEMG software) Child's perception of the seating condition in terms of pleasantness – smiley scale (from 1 to 5, where 5 denoted 'very pleasant' and 1 'very unpleasant')	Forward tilting (FW-tilting) of the seat surface with or without foot-support did not affect head stability during reaching in ambulatory children (GMFCS I and II); children with BS-CP were worse off during FW-tilting (reaches with a longer path and duration). Seating condition did not have a significant effect on head sway; affects the kinematics of reaching. Children with ambulatory BS-CP have better reaches when they sit on a horizontal seat surface. In children with US-CP, FW-tilting was associated with movements with a larger feedforward control component, whereas in children with BS-CP the horizontal seat was associated with this effect. FW-tilting with foot-support was associated with a higher average velocity of reaching in all children.

TABLE 2 – Summary of studies Non-RCT

Reference	Design Level of Evidence Method Quality	Participant Details	Description & Frequency - Intervention Group - Control Group	Assessment and Outcome Measures	Results & Conclusions
(Tekin, Kavlak, Cavlak, & Altug, 2018)	Non-Randomized Controled Trial OCEBM III AACPDM M (5/7)	**Before and After Treatment n=15** **Gender:** 8 males, 7 females **Age gap:** 5-14y **Diagnosis:** CP – hemiplegic or diplegic **GMFCS levels** I, II and III	**Type of Intervention:** NDT NDT programs **Frequency:** one session (60 min), 2 days/week for 8 weeks. **Setting:** Clinical	Gross motor function – GMFCS and GMFM-88 WeeFIM 1 Minute Walking Test Modified TUG Test PBS Seated Postural Control Measure (SPCM)	Improvement in gross motor function and functional motor level together with postural control skills, thus independence levels in daily living activities. Improvement in balance made participants walk safer and faster. After the NDT procedure, children with CP's body alignment and upper extremity functions have improved.
(Pavão, Visicato, da Costa, de Campos, & Rocha, 2018)	Non-Randomized Controled Trial OCEBM III AACPDM W (3/7)	**TOTAL n=29** **MACS level I Group (n=18)** **Gender:** 13 males, 5 females **Age gap:** 5-15y **Diagnosis:** Spastic CP **GMFCS levels** I, II, III and IV **MACS level II and III Group (n=11)** **Gender:** 5 males, 6 females **Age gap:** 5-15y **Diagnosis:** Spastic CP **GMFCS levels** I, II, III and IV <u>NOTE:</u> contradicting information in the article about patient's GMFCS levels.	**Type of Intervention:** Assistive devices – suit orthosis Children were seated on the force plate and instructed to reach for an object 10 times with their dominant arm at a self-selected speed. Manual reaching occurred in 2 conditions: (*a*) control condition – participants seated on a force plate dressed in their usual clothes; (*b*) experimental condition – participants in the same position as in the control condition and wearing the suit-orthosis. The suit includes a vest, shorts, knee pads, and shoes. All pieces are tied together with bungee-type cords. The cords are adjustable to allow varying degrees of tension – tension of the cords according to the participant's height. **Frequency (both groups):** Immediate effect **Setting:** Lab	MACS Postural sway during manual reaching Manual reaching	Children at MACS level I had increased postural displacement during the compensatory phase of the reaching task. For these the use of the suit-orthosis may have restrained the body movements. Children at MACS levels II-III showed improved postural stability during the anticipatory phase of manual reaching while wearing the suit-orthosis. Significant influence on postural sway during manual reaching. Children with CP at MACS levels II-III appeared better aligned on visual inspection when using the suit-orthosis. While wearing the suit-orthosis resulted in a more erect position of the trunk and head, it did not affect any other body sway variables.
(Mi, Young, Yeon, Sik, & Yi, 2019)	Retrospective Study OCEBM III AACPDM M (4/7)	**TOTAL n=146** **Gender:** 82 males, 64 females **Age gap:**3-10y **Diagnosis:** Cerebral palsy – spastic (unilateral and bilateral), dyskinetic and ataxic **GMFCS levels** I, II, III and IV	**Type of Intervention:** Hippotherapy Hippotherapy treatment protocol: muscle relaxation; sustenance of optimal postural alignment of the head, trunk, and lower extremities and independent sitting; and active exercises (stretching, strengthening, dynamic balance, and postural control). **Frequency:** 30 min of hippotherapy 2x/week for 8 weeks. **Setting:** Clinical (hippotherapy center)	Gross motor skills – GMFM-88 & GMFM-66 Balance – PBS	Children with CP, GMFCS level I–III, with relatively poor postural control in sitting might have a greater chance to improve their GMFM-66 scores through hippotherapy. No influence of CP type and distribution on the increase in GMFM-66 score after hippotherapy. The greater change of GMFM-88 in unilateral CP might be attributed to the high percentage of GMFCS levels I and II in this group.

- **REPORTING OF ASSESSMENT TOOLS AND OUTCOME MEASURES**

Within the different studies (see Table 1 and 2), there were multiple assessment tools used – some standard and some non – and they ranged from tools to assess function – GMFM, MACS WeeFIM, functional fitness and mobility testing, TUG test, STS test, PEDI, PODCI, PACMI, movement analysis, gait analysis –, tools to assess postural control or related concepts such as balance and gait, as explained above – SPCM, SATCo, SAS, postural analysis (standing or sitting), gait analysis, PBS, PRT, Berg Balance Scale, Tilt board balance test, Biodex Balance System, Functional Reach Test – and tools to assess other variables – spasticity testing, pleasantness scale, game scores and even GMFCS levels.

- **INTERVENTIONS AND THEIR EFFECT**

There were eight different categories of types of interventions, some with subcategories as well. These were: 1) gait training – partial body weight suspended treadmill training (two interventions with moderate level of evidence) and backward walking training (one intervention with strong level of evidence) –, 2) hippotherapy – with a horse or a simulator (both interventions with moderate level of evidence) –, 3) balance training – Biodex® Balance System (one intervention with strong level of evidence), Wii® (one intervention with moderate level of evidence), segmental training (one intervention with strong level of evidence) and computer play (one intervention with strong level of evidence) –, 4) assistive devices – insoles (one intervention with strong level of evidence) and suit orthosis (one intervention with weak level of evidence) –, 5) SV (one intervention with moderate level of evidence), 6) P-M training (one intervention with moderate level of evidence), 7) environmental changes – seat tilting (one intervention with moderate level of evidence) and seat height adjustment and foot placement (one intervention with weak level of evidence) – and, finally, 8) NDT (one intervention with moderate level of evidence). Overall, seven (all except SV) out of the eight interventions showed some positive effects – 15 (all but SV) out of 16 if we consider subtypes –, two (environmental changes and assistive devices) out of the eight interventions showed negative effects, even though it was only for part of their sample – two (seat tilting and suit orthosis) out of 16 if we consider subtypes – and five (gait training, hippotherapy, balance, SV and environmental changes) out of the eight interventions did not show better nor worse effects, when compared to control interventions – eight (treadmill with PBWSTT, hippotherapy simulator, Wii®, segmental training, interactive computer play, SV, seat height and seat tilting) out of 16 if we consider subtypes.

QUALITY AND BIAS ASSESSMENT

As mentioned above and is highlighted in the Appendix, three out of the 10 studies with OCEBM level 2 responded negatively to the AACPDM question regarding bias – gait training with BWSTT, balance training with Wii® and SV – and out of the remaining 6 studies with OCEBM levels 3-4, two also responded negatively – environmental alteration (seat height) and assistive devices (suit orthosis). Only four out of the 10 studies with OCEBM level 2 responded positively to the AACPDM question regarding masking of assessors – gait training (backward walking training), assistive devices (postural insoles) and balance training (segmental training and interactive computer play). There were five studies with strong level of evidence, nine studies with moderate level of evidence and two studies with weak level of evidence – study quality ratings are included in Table 1 and 2.

RESULTS OF INDIVIDUAL STUDIES

Positive and negative outcomes, as well as the outcomes of intervention groups that did not show benefits over controls, have been previously reported in the present study, however, it is important to analyze them in the light of group characteristics, as well as frequency and duration of interventions. Note that all of the articles are part of the results of the search using combination A – regarding function – and only two (El-Shamy & El Kafy, 2014; Mi, Young, Yeon, Sik, & Yi, 2019) of the total articles found are part of the results of the search using combination B – participation – and C – function and participation. The information that follows, regarding each individual study, is organized by type of intervention.

Gait training interventions

Johnston et al. (2011) presents a group of 26 participants, aged between 6 and 13, with spastic CP and GMFCS levels between II and IV. Intervention period lasted 10 weeks and intervention itself happened five times a week for 30 minutes. Intervention consisted in supported speed treadmill training program, as opposed to control group that did an exercise program for spasticity, strength, motor control, gait speed, gross motor skills and physical function. Their hypothesis that the IG would show greater gains overall was not supported, as children in both groups increased gait speed after the intervention. However, only the PBWSTT group maintained this improvement after the intervention was withdrawn and only children in the PBWSTT group showed gains in gait spatiotemporal parameters and functional activity (PODCI global scores), which were also maintained without continued intervention, suggesting carryover effects. There were three minor adverse effects – two children had discomfort in the lower limbs while walking on the treadmill and one developed a blister with the ankle-foot orthosis, which resolved with no intervention, therefore those were not accounted for as negative effects (Johnston, et al., 2011).

El-Basatiny & Abdelaziem (2014), presents a group of 30 participants, aged between 10 and 13, with spastic hemiparetic CP and GMFCS levels between I and II. Intervention period lasted 12 weeks and intervention itself happened three times a week for 60 minutes. Intervention consisted in backward walking training in addition to the traditional physical therapy program for postural control, as opposed to control group that only did the traditional physical therapy program. From the results of this study, it seems that backward walking, in combination with traditional physical therapy, is more effective in improving balance ability – seen in the higher improvement in anteroposterior, mediolateral and overall stability indices compared with the CG –, in children with spastic hemiparetic cerebral palsy, than traditional physical therapy exercise alone (El-Basatiny & Abdelaziem, 2015).

Wallard et al. (2018) presents a group of 30 participants, aged between 8 and 10, with bilateral spastic CP and GMFCS level II. Intervention period lasted four weeks and intervention itself happened five times a week for 40 minutes. Intervention consisted in the use of the Lokomat® Pediatric for gait training with partial body weight support (PBWS) – initially 70% body-weight support that was then gradually decreased to 40% over the sessions, according to the participant's functional capacity –, as opposed to control group that continued their program of physical or occupational therapy with a physiotherapist. The study demonstrates that robotic gait rehabilitation seems to present beneficial effect on recovery and improvement of postural and locomotor functions of the participants. These improvements result in a reorganization of gait pattern – significant increase in gait speed and step length, which were associated with a significant decrease in cadence and step width highlighting a dynamic control, as well as decreased average of the double support time was observed associated with an increased average of the single support time –, which become quantitatively more harmonious – significant improvement in gait symmetry – and effective – the participants were able to walk a greater distance for an equivalent duration to that of a physiotherapy session. This represents, for the IG, better postural stability and control of dynamic balance during imbalance phases. Results also showed task-specific improvements in gait parameters as measured by the dimension E of the GMFM, which suggests an additional effect on the stabilization of posture beyond the task-specific improvement of walking parameters (Wallard, Dietrich, Kerlirzin, & Bredin, 2018).

Hippotherapy interventions

Herrero et al. (2012) presents a group of 38 participants, aged between 7 and 11, with CP and all GMFCS levels. Intervention period lasted 10 weeks and intervention itself happened once a week for 15 minutes. Intervention consisted in sitting on the hippotherapy simulator with active extension of the trunk while the simulator was on “workout” mode, as opposed to control group that had the simulator turned off. This protocol was in addition to the children’s routine therapy program, therefore, the main finding of the study suggests that this intervention may help improve sitting balance in children with CP. The study points to better effects with children with higher levels of disability, suggesting that perhaps the duration of the sessions or the intensity of therapy was not sufficient to cause changes in patients with higher levels of ability (Herrero, et al., 2012).

Mi et al. (2019) presents a group of 146 participants, aged between 3 and 10, with spastic, dyskinetic and ataxic CP and GMFCS levels between I and IV. Intervention period lasted 8 weeks and intervention itself happened two times a week for 30 minutes. Intervention consisted in a hippotherapy treatment protocol that includes muscle relaxation, sustenance of optimal postural alignment of the head, trunk, and lower extremities and independent sitting, as well as active exercises (stretching, strengthening, dynamic balance, and postural control) directed by the therapist. The participants were encouraged to maintain postural alignment during all the activities and the intensity of the exercises and degree of assistance were individualized according to the participants’ ability to control their posture. This study found that children with CP, GMFCS levels I and II or III, with relatively poor postural control in sitting might have a greater chance to improve their GMFM-66 scores through hippotherapy (Mi, Young, Yeon, Sik, & Yi, 2019).

Balance training interventions

El-Shamy & El-Kafy (2014) present a group of 30 participants, aged between 10 and 12, with spastic diplegic CP and GMFCS levels between I and II. Intervention period lasted 12 weeks and intervention itself happened three times a week for 30 minutes. Intervention consisted in balance training with the Biodex® Balance System, as opposed to control group that followed a NDT program. Initial results showed no significant differences in the ability to control balance and to minimize the risk of fall in both groups – the mean values of the two parameters measured in the dynamic limit of stability test (overall directional control and total time to complete the test) and the overall stability index of the fall risk test from pre- to post-treatment –, however significant improvement was observed post-treatment in favor of IG in reactive balance control, therefore, showing benefits related to postural balance control and risk of fall. This study also mentions the adverse influence of balance deficits on subjects' performance of different daily activities and how this may affect their participation in home, school and community life, therefore suggesting that this could be an effective, easily applicable, objective method in improving a child's balance ability (El-Shamy & El Kafy, 2014).

Tarakci et al. (2016) presents a group of 30 participants, aged between 7 and 13, with spastic diplegic, spastic hemiplegic and dyskinetic CP and GMFCS levels between I and III. Intervention period lasted 12 weeks and intervention itself happened two times a week for 50 minutes. Intervention consisted in Wii-Fit® balance based video games (ski slalom, tightrope walk and soccer heading on balance board), in addition to NDT (activities for regulating tone, work that supports sense-perception-motor development, activities that facilitate regular movement, stretching and strengthening exercises for musculoskeletal disorders, functional skills training for upper extremity, and training in daily living activities such as dressing and eating), as opposed to control group that did balance training (exercises with the balance board and trampoline, mat exercises, weight-shifting exercises and walking activities) and the same NDT program as IG. Intervention with the Wii-Fit® demonstrated generating improvement on balance parameters and independence level in activities of daily life – even though WeeFIM Transfers subscores did not change statistically significantly after treatment in both groups, changes in all other primary and secondary outcome measures were significant, in favor of the IG (Tarakci, Huseyinsinoglu, Tarakci, & Ozdinçler, 2016).

Curtis et al. (2017) presents a group of 28 participants, aged between 2 and 15, with spastic and dyskinetic CP and GMFCS levels between III and V. Intervention period lasted 6 months and intervention itself happened five times a week for up to 30 minutes. Intervention consisted in segmental training of head and trunk control, as opposed to control group that was subjected to their usual physical therapy programs, which weren't standardized. The study suggests that segmental training for children and young people with moderate-to-severe CP was not superior to conventional physiotherapy in improving gross motor function, functional mobility or trunk control (change in GMFM did not differ between groups, no significant differences between groups in the change in PEDI or SATCo scores), however, improvements in head and trunk sway (sagittal plane trunk sway amplitude was significantly reduced) were greater in the IG – although not at follow-up. (Curtis, et al., 2018).

Pin & Butler (2019) present a group of 18 participants, aged between 6 and 11, with bilateral spastic CP and GMFCS levels between III and IV. Intervention period lasted six weeks and intervention itself happened four times a week for 20 minutes. Intervention consisted in keeping their usual physiotherapy program (motor control and muscle strength) and adding trunk control training using the interactive computer play in sitting (TYMO®, a commercial portable force plate is specifically designed to assess and treat postural control and suitable for the therapy of neurological and orthopedic patients of all ages), as opposed to control group that only kept their usual physiotherapy program (motor control and muscle strength). Although the intervention appears to be feasible and safe in the setting of special schools for children with physical disabilities, the preliminary findings of this study showed that this training program did not confer extra benefit in improving sitting balance and gross motor function for the participants – both groups generally improved their sitting balance and functional gross motor skills and this was particularly true of the PRT and the Gross GMFM–66-Item (Pin & Butler, 2019).

Assistive devices

Christovão et al. (2015) presents a group of 20 participants, aged between 4 and 9, with spastic diplegic CP and GMFCS levels between I and II. Intervention period lasted 12 weeks and it consisted in the daily use of postural insoles, as opposed to control group that didn't wear these corrective elements. Postural insoles led to an improvement in static balance, as demonstrated by the reduction in body sway in the anteroposterior and mediolateral directions, as well as leading to improved performance on the TUG test, thus showing improvements in both static balance and in mobility. This seems to suggest that there is a change in sensorial afference, stimulating a postural reaction that favors a better biomechanical alignment of the body and permits more efficient function (Christovão, et al., 2015).

Pavão et al (2018) presents a group of 29 participants, aged between 5 and 15, with spastic CP and GMFCS levels between I and IV. Intervention was assessed immediately, as it consisted in the performance of a manual reaching task while wearing a suit orthosis that included a vest, shorts, knee pads and shoes. Manual reaching occurred in two conditions: control condition, with participants seated on a force plate dressed in their usual clothes, and experimental condition, with participants in the same position as in the control condition and additionally wearing the suit-orthosis – participants performed 10 trials in each of the conditions. The suit-orthosis had significant influence on postural sway during manual reaching, particularly in children at MACS levels II-III, and it improved postural stability for children at MACS levels II-III during anticipatory adjustments of manual reaching. Although kinematics were not used to analyze postural alignment, children with CP at MACS levels II-III appeared better aligned on visual inspection when using the suit-orthosis. While wearing the suit-orthosis resulted in a more erect position of the trunk and head for these participants, it did not affect any other body sway variables. For children at MACS level I, who are able to dissociate upper limb from trunk movements, the use of the suit-orthosis may have restrained the body movements while the participants attempted to overcome elastic resistance, thereby increasing the displacement of the trunk forward and resulting in greater sway (Pavão, Visicato, da Costa, de Campos, & Rocha, 2018).

Stochastic Vibration

Kyvelidou et al. (2017) presents a group of 30 participants, aged between 2 and 6, with bilateral spastic, dyskinetic, dystonic and non-classifiable CP and GMFCS levels between II and IV. Intervention period lasted 12 weeks and intervention itself happened two times a week for 60 minutes. Intervention consisted in standard of care consultative physical therapy (once every week, focusing on equipment management, training for functional activities, such as transfers and wheelchair mobility, and training of staff to manage positioning and adaptive equipment), perceptual-motor therapy (ecological approach, based on spontaneous movement that uses handling and self-initiated, functionally directed movement to find solutions to movement problems) and stochastic vibration (SV) to the seating surface during therapy, as opposed to control group that received the same standard of care consultative physical therapy and perceptual-motor therapy, but no SV. The results of this study point to the fact that adding SV stimulus during intervention does not appear to have an effect on the development of the sitting skill. There was an improvement in GMFM scores in all children, indicating positive gross motor function changes as a result of the perceptual-motor treatment, but not due to the addition of SV. Therefore, due to the significant changes noted in sitting scores and single-subject analysis, the use of the perceptual-motor therapy seems to be supported, as a means of advancing sitting postural control in children with moderate or severe CP who are between the ages of 2 and 6 years (Kyvelidou, Harbourne, Haworth, Schmid, & Stergiou, 2018).

Environmental changes

Lazzeri de Medeiros et al. (2015) presents a group of 14 participants, aged between 6 and 12, with diplegic and quadriparetic spastic CP and GMFCS levels between I and III and another group of 14 participants (typically developing), aged between 6 and 12. Intervention was assessed immediately, as it consisted in adjusting seat height and foot placement in children with CP (IG) and typically developing (CG). The results of this study point to the conclusion that seat height and foot placement do not influence postural control in children with CP in terms of kinetic parameters, however, it does influence kinematic variables – highlighting the importance of encouraging posterior positioning of the feet and increasing displacement of the trunk during the movement of sitting to standing. The study further adds that, when necessary, support should be provided while children are being trained for this task, as it may provide benefits like increased muscle strength of lower limb extensors and improved selective motor control (Lazzeri de Medeiros, et al., 2015).

Anguspaisal et al (2017) presents a group of 19 participants, aged between 6 and 12, with spastic CP and GMFCS levels between I and III. Intervention was assessed immediately, as it consisted in forward tilting of the seat with foot support. The results indicated that seating condition did not have a significant effect on head sway, but did affect the kinematics of reaching and that FW-tilted seating condition was associated with better and faster reaching in ambulatory children with US-CP, while horizontal seating resulted in better kinematics of reaching in ambulatory children with BS-CP. Foot-support in either horizontal or FW-tilted seating did not affect head stability or reaching parameters that largely rely on feedforward control. Foot-support in the FW-tilting was, however, associated with a higher reaching speed in all children, and affected path length and movement duration − an effect that differed for the two subgroups of CP (for participants with US-CP, FW-tilting was associated with movements with a larger feedforward control component, whereas in those with BS-CP the horizontal seat was associated with this effect) (Angsupaisal, et al., 2017).

Perceptual-motor intervention

Ryalls et al. (2016) presents a group of 30 participants, aged between 1 and 6, with CP – no information was disclosed about GMFCS levels. Intervention period lasted 12 weeks and intervention itself happened two times a week for 45 minutes. Intervention consisted in perceptual-motor training – where environmental forces are used during self-initiated goal-directed movements to change function and postural control. Overall, activities were aimed at teaching the child to attend to significant environmental information, while the therapist presented an environmental modification requiring a small movement or postural challenge to the child, and waited for the child to solve the problem, giving very light cues or assistance. This study demonstrates that an ecological intervention can significantly improve sitting ability – GMFM sitting scores improved from pre- to post-intervention – in children with moderate to severe CP, and that these improvements in sitting may lead to improvements in simple pretend play, particularly for more severely delayed children – results revealed that improvements in play were directly linked to improvements in sitting for children over 3-years of age (Ryalls, et al., 2016).

NDT

Tekin et al (2018) presents a group of 15 participants, aged between 5 and 14, with hemiplegic or diplegic CP and GMFCS levels between I and III. Intervention period lasted 8 weeks and intervention itself happened two times a week for 60 minutes. Intervention consisted in NDT programs planned specifically for each patient according to their needs and which contained vestibular and proprioceptive training on balance board or exercise balls, dynamic balance training in sitting, kneeling and standing position (eyes open and closed), balance exercises in front of the mirror, standing on one foot for improving the proprioceptive input (eyes open and closed), balance training on the trampoline, sensory stimulation for foot soles with various materials, weight bearing exercises in sitting, crawling, kneeling and standing position, functional reaching and ball throwing-keeping exercises in various positions, multitask trainings, walking, climbing up & stepping down the stairs (supported-unsupported, symmetric, reciprocal etc). It appears, through the results of this study, that an NDT based posture and balance training, applied to diparetic and hemiparetic children with CP, improved their functional motor level (functional endurance tests, PBS and WeeFIM), together with postural control skills, thus influencing in a positive manner independence levels in daily living activities, as well as balance and gait – walking faster and better (Tekin, Kavlak, Cavlak, & Altug, 2018).

DISCUSSION

As for the main purpose of this study, it can be said that 16 studies were identified, with eight different types of interventions that target postural control and that report the influence of such interventions in function outcomes – with standardized and non-standardized measures – for children with CP. Two of these studies also report on participation using descriptive analysis, not specific outcome measures. This suggests that, although the main focus of postural control interventions is their direct primary outcomes (postural control outcomes), these interventions also focus on secondary outcomes such as function and participation – the prior more than the latter –, thus demonstrating the influence of different types of interventions that target postural control on those two parameters.

The interventions with positive outcomes in postural control and functional outcomes and with higher levels of evidence – strong AACPDM classification and all OCEBM level 2 – were balance training using the Biodex® Balance System (El-Shamy & El Kafy, 2014), gait training using backward walking training (El-Basatiny & Abdelaziem, 2015) and assistive devices, specifically, postural insoles (Christovão, et al., 2015). Note that the study that uses the Biodex® Balance System also reports – descriptively – on participation, in the sense that balance deficits “have an adverse influence on the subjects’ performance of different daily activities and affect their participation in home, school and community life” and therefore, benefits to one area may extend to the other (El-Shamy & El Kafy, 2014). All these interventions were for children with CP classified as GMFCS levels I and II, which limits the results to these functional levels, however, this is relevant information with view to evident-based practice. Interventions happened three times a week for all abovementioned studies, except the use of postural insoles, which was daily. That suggests a minimum of three times a week for results to be noticeable in this segment of the population of children with CP, but it is outside the scope of the present study to infer on intervention dosage. Balance training and gross motor training have been described as important interventions that target postural control, both of which are mentioned in a systematic review as interventions with moderate evidence to improve postural control in children with CP (Dewar, Love, & Johnston, 2015). With that in mind and with the information of the present systematic review – in this case, balance training using the Biodex® Balance System and gait training through backward walking training –, it is possible to say that these interventions may be used with children with CP with a view to improving postural control outcomes and an influence on functional parameters too, with some level of confidence in children with spastic CP classified as GMFCS levels I and II. More studies are needed to assess results in other types of CP and other functional levels.

Interventions that focused on balance training using segmental training (Curtis, et al., 2018) and interactive computer play (Pin & Butler, 2019) were equally high evidence studies. However, these studies pointed to the fact that these interventions don’t seem to bring any advantage, in comparison to a traditional physical therapy program, for children with CP classified as GMFCS levels III to IV in both cases, with the added level V children for the segmental training. This is relevant information for the decision-making process based on the best possible evidence for clinicians in the field, especially taking into account that both those interventions were intensive. Notice that segmental training took place five times a week and interactive computer play four times a week, and even so, the results weren't better than those of conventional physical therapy programs. That suggests that these interventions, even when applied in an intensive manner, do not have superior impact on postural control and function than conventional programs of physical therapy. However, for both of these studies, as well as some others, the definitions and frequency of the intervention of the "traditional or standard physical therapy programs" weren't defined or clear. That poses a major difficulty when reviews such as this one want to report on those interventions, as they are not documented and, therefore, cannot be accurately replicated. This is not exclusive to the present study, being relatively frequent in the literature (Morgan, et al., 2016).

Interventions with positive outcomes in postural control and functional outcomes and with moderate levels of evidence – moderate AACPDM classification and all OCEBM levels 2, 3 and 4 – were gait training with PBWSTT – with treadmill (Johnston, et al., 2011) and with the Lokomat® system (Wallard, Dietrich, Kerlirzin, & Bredin, 2018) –, hippotherapy with a simulator (Herrero, et al., 2012) and with a horse (Mi, Young, Yeon, Sik, & Yi, 2019), balance training with Wii® system (Tarakci, Huseyinsinoglu, Tarakci, & Ozdinçler, 2016), perceptual-motor techniques (Ryalls, et al., 2016), environmental changes, namely forward tilting of the seat (Angsupaisal, et al., 2017) and NDT (Tekin, Kavlak, Cavlak, & Altug, 2018). Both kinds of interventions with PBWSTT happened in an intensive manner, presenting good results with regard to gait speed and some functional improvements – regarding balance and other parameters. However, better results were noted in the study that used the Lokomat® system. This is to be expected, as the participants were classified as GMFCS level II, as opposed to the other study that included a much less homogenous group (GMFCS levels II to IV). Therefore, more studies are needed in order to assess results for children classified as level III and IV of the GMFCS. It seems, however, that this appears to be a safe and effective intervention for children classified as GMFCS level II, focusing on gait training, with outcomes in postural control in standing (postural stability) and functional mobility (dynamic control). Hippotherapy with a simulator was used with children with CP classified as levels I to V and it was applied once a week for 15 minutes. This intervention seems to have had a positive effect on the sitting balance of the children with higher levels of disability, but not for ones with higher levels of ability. This is likely to be due to the fact that the intensity and frequency was enough for the first group and not for the second. What is more, there were no benefits regarding overall function for children classified as GMFCS level V, which appears to denote that even though there were benefits regarding sitting balance, these did not translate into functional outcomes and contexts in the children's lives. As for hippotherapy with a horse, it was used with children classified as GMFCS levels I to IV and effects were opposite to the results of the hippotherapy with a simulator in the sense that GMFM scores showed better results in children classified with GMFCS levels I to III and, specifically, sitting postural control too. This makes sense in the context of this study, seen as the intervention was more frequent and the duration of the sessions was twice as long. This study reported descriptively on participation measures, stating that "children's participation in activities at home, school, and community is one of the most important outcomes of rehabilitation interventions, because it is fundamental to their health and development" and adding that "most traditional interventions for children with CP focus primarily on factors in the domain of body function and structure", but hippotherapy is an emerging therapy intervention for children with physical disabilities, which suggests focusing the changes in the "environment and/or the activity demands (i.e., context-focused therapy) rather than on directing change to the child's abilities (i.e., child-focused therapy)" – representing, therefore "a useful approach to improve function and participation" (Mi, Young, Yeon, Sik, & Yi, 2019). Hippotherapy has traditionally been associated with alterations in body function and structure, utilizing "equine movements as part of a comprehensive program of intervention aimed at improving functional outcomes because it enhances the muscle tone, balance, and coordination through horseback riding" (Mutoh, et al., 2019). Therefore, it is unclear how this therapy is considered context-focused and how it, without further description or outcome measures, qualifies as an intervention with an impact on participation, which means that these results must be analyzed with caution and in light with this information. Balance training with the Wii® system, NDT and both the environmental changes studies all included children classified as GMFCS I to III and happened twice a week. There were positive results following all these interventions, however, not in all parameters. Balance training using the Wii® system lead to better outcomes in all measures except WeeFIM; NDT lead to better outcomes in GMFM scores, walking, posture and balance control, as well as in independence levels in ADLs; finally, in the environmental changes study showed mixed results, in that forward seat tilting appears to be of benefit for UL-CP but not for BL-CP. As for the perceptual-motor intervention, two distinct sources of information are relevant – the article about the P-M intervention in itself (Ryalls, et al., 2016) and the article about SV (Kyvelidou, Harbourne, Haworth, Schmid, & Stergiou, 2018). The first article includes children with moderate to severe CP, which isn't the most accurate way to report on children's characteristics (Wood & Rosenbaum, 2007). This article reports positive effects on GMFM scores and sitting ability, as well as better results in play, even though the intervention did not target play. It appears to support the use of this type of intervention in young children (one to six years old), highlighting the link between sitting ability, function (play) and cognition. The second article uses P-M intervention as a complement to conventional therapy, twice a week, and both groups improved. This study includes two to six year old children classified as GMFCS levels II to IV and results are noticed in GMFM outcomes. This information suggests, therefore, that P-M interventions seem to have positive results in young children's sitting postural control and functional outcomes such as play and GMFM. This is in line with a study that mentions that P-M intervention appears "to provide greater flexibility and adaptability of the skill (sitting), which may translate to ease of further motor development" (Harbourne, Willett, Kyvelidou, Deffeyes, & Stergiou, 2010).

Interventions with positive outcomes in postural control and functional outcomes and with low levels of evidence – weak AACPDM classification and OCEBM levels 3 and 4 – were environmental changes, namely seat height and foot placement (Lazzeri de Medeiros, et al., 2015), and assistive devices, specifically the suit orthosis (Pavão, Visicato, da Costa, de Campos, & Rocha, 2018). It appears that seat height influences the mechanical demands of the "sitting to standing" functional task (higher seats are easier), but not the time it takes to accomplish it, and it influences postural control in kinematic parameters (observed with a camera), but not kinetic (COP displacement). These conclusions are applicable to children with GMFCS classifications of I to III that, by classification definition, are able to self-transfer (sit to stand) (Palisano, Rosenbaum, Bartlett, & Livingstone, 2007). As for the suit orthosis, mixed results were found in that for children with MACS II and III the effects were positive – better postural stability and better body alignment – but not for those with MACS I, as will be discussed next in the present study.

The only negative outcomes were related to the restriction of movement created by the suit orthosis for children with higher functional levels (MACS I), in that they presented worse postural displacement with the suit than without it – probably because the suit restricted their movements in the functional task of reaching –, and the negative effect of forward seat tilting on posture for children with bilateral spastic CP, in that these have better reaching when the seat is horizontal, not tilted.

There were also a few interventions that did not show any advantage, compared with standard physical therapy intervention programs, all of which have already been reported on in the present study except for SV, which seems to not have had any beneficial influence on sitting, postural sway, postural control and overall GMFM results. However, that same study reports on the positive results that apparently came from the use of P-M therapy, as previously reported in the present systematic review. Some studies also reported momentary adverse events that must be taken into account and avoided in clinical practice, if possible, such as blisters due to AFOs and discomfort linked to increased levels of physical activity. This is relevant information for all intervention types, seen as the patient's wellbeing is of the utmost importance at all times, therefore, inspection of potential injury sites must happen.

Six studies (El-Shamy & El Kafy, 2014; El-Basatiny & Abdelaziem, 2015; Curtis, et al., 2018; Kyvelidou, Harbourne, Haworth, Schmid, & Stergiou, 2018; Wallard, Dietrich, Kerlirzin, & Bredin, 2018; Pin & Butler, 2019) were not clear as to what the control group's intervention was, as was already lightly discussed above, and those that do mention the intervention tend not to go into detail – such as Frequency, Intensity, Time and Type (FITT). This poses a big difficulty in, not only understanding truly what the intervention group is being compared to, but also in using the results in clinical practice for evidence-based decision making. Even if the interventions are the same in both groups and the intervention group simply has an addition of some other type of therapy, as is what happens in some of the studies analyzed for the present systematic review, it would be important to know exactly what was done. This has been described multiple times (Morgan, et al., 2016) and it is highly recommended that studies include thorough descriptions of intervention programs, as to not lead to bias and difficulty in translating research into clinical practice. Another issue that leads to difficulty in study comparison is the lack or poor usage of outcome measures, standard or not, to assess and compare participants' results in studies – intervention versus control groups. This is true for the different variables that were assessed in the studies included in the present systematic review, namely postural control and function, but especially participation. Outcome measures for participation exist, however, they were not used in any study included in this systematic review. Future studies may focus more thoroughly on measuring the impact of postural control interventions on participation, by means of instruments, as will be highlighted bellow.

So, in answer to the question posed in the title of the present study "Do Physical Therapy Interventions that Target Postural Control Influence Function and Participation Outcomes in Children with Cerebral Palsy?" it can be said, according to present findings, that yes, some interventions do. However, studies appear to be much more focused on function than participation, which is to be expected, as physical therapy presently tends to be more centered in recovery or attainment of function and the return to or accomplishment of activity, than centered in achieving or recovering active participation in one's social and physical context. It has been described that "approaches using individually tailored education and mentoring programs were found to enhance participation outcomes, while exercise programs, where participation was a secondary outcome, generally demonstrated little effect" (Adair, Ullenhag, Keen, Granlund, & Imms, 2015). So, regarding participation, the question is, truly, "how are children with CP participating and how can physical therapy interventions help them participate more and better?" A study on teenagers with CP highlights the "importance of personal and environmental factors in overcoming these difficulties" (Wintels, Smits, van Wesel, Verheijden, & Ketelaar, 2018). Physical therapy interventions can and should target both those factors, in addition to body functions and structures. In order to do that, researchers and practitioners need "to measure what they are trying to accomplish" (Chiarello L. , 2017) and there are multiple instruments that can be used to assess participation, such as the CAPE (Shikako-Thomas, et al., 2012; Orlin, et al., 2010) or the Goal Assessment Scale (GAS), which permits establishing participation-centered goals and the assessment of such in the child's context (Chiarello, Effgen, Jeffries, McCoy, & Bush, 2016). Their use may facilitate understanding how physical therapy interventions actually influence participation. Orlin et al (2009) highlights that the participation in one or two new activities in the child's context may be enough to "have a large impact on their quality of life" and Chiarello (2017) highlights that sometimes the goals set by the clinicians are not the most important for the children. Therefore, it is ever more and more important to consider participation outcomes in children with CP, in view to what they themselves want, seen as there is a crescent need for our research and practice to be "directed toward the environment and building a community to foster participation" (Chiarello L. , 2017). Interestingly many studies included in the present systematic review were carried out in a clinical or lab-type environment. However, when considering function and participation, it is crucial to understand and work with and within the child's context, which may include school-based interventions, home programs, community programs or others. More studies are needed to understand the impact of context-focused physical therapy interventions in function and participation outcomes.

CONCLUSIONS

In conclusion, the present study's recommendation of appropriate management of postural control dysfunction, with view to function, suggests the use of balance training using the Biodex® Balance System, backward gait training and the use of postural insoles with high level of recommendation for children with spastic CP levels I and II of the GMFCS. For those of levels III-V the evidence is moderate, however, interventions such as P-M therapy (for GMFCS III and IV) and small dosage of treatment using the hippotherapy simulator (for GMFCS V) show some promise. As for the appropriate management of postural control dysfunction, with view to function and participation or just participation, it is difficult to suggest any intervention, seen as there were no outcomes related to the latter. However, studies such as El-Shamy & El Kafy (2014) – balance training with the Biodex® Balance System – and Mi et al (2019) – hippotherapy – show promise in the sense that participation was mentioned as an important parameter to take into account in therapeutic interventions. However, studies that use outcome measures related to participation, in addition to postural control and function, are paramount to understand the impact of those interventions in the children's life. Therefore, more studies are needed to verify the impact of all the other abovementioned types of interventions with children of different GMFCS levels with a view to improving function and participation outcomes, in addition to those related to postural control.

LIMITATIONS AND SUGGESTIONS FOR FUTURE STUDIES

This study has some limitations, some of which have been mentioned above. Other limitations are: firstly, there are no OCEBM level 1 studies, therefore, this is not a systematic review of systematic reviews, which would represent a higher level of evidence. Secondly, the article selection was done only by the main author up until the eligibility analysis of the full texts; therefore, there is a possibility of bias in the prior selection of articles. Thirdly, no specific instrument was used to assess bias in the different studies, seen as the instrument that assessed the articles had one parameter that included this analysis. However, it is important to assess risk of bias in a more standardized way to allow for better comparison between studies. Fourth, overall participants were very heterogeneous, making it more difficult to compare studies and outcomes. Fifth, even though the family of participation-related constructs was considered for the data extraction process, it was not successful, therefore, it is suggested that these may be used as key-words in future database searches.

More studies are needed, with broader scopes than the present one, in order to distinguish type and dosage of intervention within children with specific functional profiles. Also, it would be interesting to break down the concepts related to function and participation, according to ICF domains, for example, and study the influence of interventions that target postural control in those. Further, more studies are required to demonstrate the importance of postural control training on function and participation measures and the impact of such in the lives of these children – including concepts such as Quality of Life and others.

SUMMARY OF EVIDENCE

- The present study's recommendation of appropriate management of postural control dysfunction, with view to function:
  - For children classified as GMFCS level I and II: suggests the use of balance training using the Biodex® Balance System, backward gait training and the use of postural insoles, with high level of evidence.
  - For children classified as GMFCS III-V: the evidence is moderate, however, interventions such as P-M therapy (for GMFCS III and IV) and small dosage of treatment using the hippotherapy simulator (for GMFCS V) show some promise.

MESSAGES TO TAKE HOME

- For physical therapists: interventions that target postural control seem to influence function – more clearly – and participation – less clearly. Focusing on the best available evidence to base clinical practice will help enhance treatment results. Focusing on patients' real needs in terms of function and participation may lead to higher levels of patient involvement and motivation and therefore, stronger, better outcomes.
- For investigators: more studies are needed, especially with regards to the impact of interventions that target postural control on participation outcomes.
- For parents: be partners in rehabilitation – always –, share your function and participation goals, as well as those of your child, with your therapist.
- For children with CP: don't shy back from explaining what you would like to do (example: play soccer) and where/with whom you'd like to do it (at school with your colleagues)! Your functional and participation-related goals are of utmost importance, be sure to let your physical therapist know what drives you, so that interventions can be catered to your needs and likes!

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Appendix

Quality Level 2 OCEBM								
Study	**Quality Level**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
(Christovão, et al., 2015)	II-S (7/7)	Y	Y	Y	Y	Y	Y	Y
(Curtis, et al., 2018)	II-S (7/7)	Y	Y	Y	Y	Y	Y	Y
(El-Shamy & El Kafy, 2014)	II-S (6/7)	Y	Y	Y	N	Y	Y	Y
(El-Basatiny & Abdelaziem, 2015)	II-S (6/7)	Y	Y	Y	Y	N	Y	Y
(Pin & Butler, 2019)	II-S (6/7)	Y	Y	Y	Y	N	Y	Y
(Wallard, Dietrich, Kerlirzin, & Bredin, 2018)	II-M (5/7)	Y	Y	Y	N	N	Y	Y
(Johnston, et al., 2011)	II-M (4/7)	Y	Y	Y	N	Y	N	N
(Herrero, et al., 2012)	II- M (4/7)	N	Y	Y	N	N	Y	Y
(Tarakci, Huseyinsinoglu, Tarakci, & Ozdinçler, 2016)	II-M (4/7)	Y	Y	Y	N	N	Y	N
(Kyvelidou, Harbourne, Haworth, Schmid, & Stergiou, 2018)	II-M (4/7)	Y	Y	Y	N	N	Y	N
Quality Level 3 and 4 OCEBM								
Study	**Quality Level**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
(Tekin, Kavlak, Cavlak, & Altug, 2018)	III-M (5/7) [Non-Randomized Controled Trial]	Y	N	Y	N	Y	Y	Y
(Ryalls, et al., 2016)	III-M (4/7) [Non-Randomized Controled Trial]	Y	N	Y	N	N	Y	Y
(Angsupaisal, et al., 2017)	IV-M (4/7) [Exploratory Study]	N	N	Y	N	Y	Y	Y
(Mi, Young, Yeon, Sik, & Yi, 2019)	III-M (4/7) [Retrospective Study]	Y	N	Y	N	N	Y	Y
(Lazzeri de Medeiros, et al., 2015)	IV-W (3/7) [Case Control Study]	Y	N	Y	N	N	Y	N
(Pavão, Visicato, da Costa, de Campos, & Rocha, 2018)	III-W (3/7) [Non-Randomized Controled Trial]	Y	N	Y	N	N	Y	N

Conduct Questions (group interventions)

1. Were inclusion and exclusion criteria of the study population well described and followed?

2. Was the intervention well described and was there adherence to the intervention assignment? (for 2-group designs, was the control exposure also well described?) Both parts of the question need to be met to score 'yes'.

3. Were the measures used clearly described, valid and reliable for measuring the outcomes of interest?

4. Was the outcome assessor unaware of the intervention status of the participants (i.e., were the assessors masked)?

5. Did the authors conduct and report appropriate statistical evaluation including power calculations? Both parts of the question need to be met to score ‘yes’.

6. Were dropout/loss to follow-up reported and less than 20%? For 2-group designs, was dropout balanced?

7. Considering the potential within the study design, were appropriate methods for controlling confounding variables and limiting potential biases used?

(AACPDM, 2020)

3. Conclusions and Final Considerations

The present Master's Dissertation discussed the influence of physical therapy interventions that target postural control in function and participation outcomes in children with cerebral palsy. It was possible to see that functional outcomes are accounted for, when it comes to studies that report on interventions with the aim of managing postural control dysfunction. However, the same cannot be said about those related to participation. Suggestions were made regarding future lines of investigation, in order to continue to pursue this very timely topic.

Using the best available knowledge, it is paramount that physical therapists adapt to the changing paradigms of intervention, namely, with a focus on function, participation and overall quality of life, rather than sticking solely to the attempt of "fixing" dysfunction. It is important to prepare children for their life, using the functional skills they have, as well as to teach them to look for and find opportunities to use the tools we equip them with in their day to day life – thus highlighting the physical therapist's role as a clinician, an educator and an ally in the promotion of healthy lifestyles. We have the privilege and the responsibility, as health professionals, to advise these children and their families on the most current and evidence-based interventions and strategies we are able to find.

The construction of this Dissertation was a very enrichening process, as a physical therapist, as a student and as an investigator. From the moment when the idea behind the theme of this document was conceptualized, until its final version, this has been an intense intellectual and academic challenge, accompanied by exponential growth of skill and knowledge. It is a small yet, I hope, meaningful contribution towards the promotion of good evidence-based practices in physical therapy in the management of postural control dysfunction in children with cerebral palsy.