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1. List of abbreviations and key terms

AGT – Antigravity Treadmill

CG – Control Group

CoM – Centre of Mass

CoP – Centre of pressure

CP – Cerebral Palsy

GMFCS - Gross Motor Function Classification System

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

MACS - Manual Ability Classification System

PBS – Pediatric Balance Scale

PC – Postural Control

Post-T – Post Treatment

Pre-T – Pre Treatment

PT – Physical Therapy

SDCP – Spastic Diplegic Cerebral Palsy

SHCP – Spastic Hemiplegic Cerebral Palsy

SG - Study Group

SHCP – Spastic Hemiplegic Cerebral Palsy

SR - Stochastic Resonance

TD – Typical Development

tDCS - Transcranial Direct-Current Stimulation

TUG – Timed Up and Go test

WBV – Whole Body Vibration

2. Introduction

2.1. Cerebral Palsy

Cerebral palsy (CP) is a permanent neurological disorder that affects movement and posture and it is considered one of the most common disabilities in childhood (Koman, Smith, & Shilt, 2004; Carlberg & Hadders-Algra, 2005). The term "cerebral" relates to the brain while "palsy" refers to weakness , paralysis or lack of muscle control. Brain injury caused during pregnancy, during birth or during the child´s two first years is considered to be the cause of cerebral palsy (Koman, Smith, & Shilt, 2004). For individuals with a diagnosis of CP. muscles, muscle tension and body functions cannot be controlled effectively by the brain as neurological signals are interrupted in some way (Levitt, 2010). Impairments due to CP can vary greatly and are dependent upon the location and extent of injury in the brain. While some individuals can be independent in their self-care, can communicate without difficult, and are highly mobile, others can be totally dependent on assistance for their self-care, non-ambulatory and have severe intellectual disability (Bax & Brown, 2004).

2.1.1. Types and Classification of CP

CP types differ depending on the location of the brain injury (Pyramidal/Spastic Cerebral Palsy or Extrapyramidal), the type of the muscle tone (Martin 2006) and the body parts which are affected (Miller & Bachrach, 2006). Table 2.1 presents the different types of CP (Levitt, 2010; Günel, 2011; Miller, 2007) .

Table 2.1 Types of CP ((Levitt, 2010; Günel, 2011; Miller, 2007)

Type According To The Brain Injury And Muscle Coordination		Affected Body parts (Topography)	
Pyramidal CP			
Spastic	Very high muscle tone, tight and limit movements.	*Hemiplegic*	One arm and one leg of the same side
Extrapyramidal CP		*Diplegic*	Mostly both legs (the arms are also affected but less)
Athetoid	**No muscle control.**		
Hypotonic	Too low muscle tone.		
Ataxic	Impairments in balance and coordination, unsteady.		
Choric			

	Abrupt, quick and jerky movements.		
Mixed	Combination of 2 or more of types	*Quadriplegic (Tetraplegic)*	All four extremities of the body (legs & arms)

The Gross Motor Function Classification (GMFCS) is the most accepted way to classify CP and is based on functional abilities and limitations of the child (Palisano et al., 1997, 2008). GMFCS is focused on the child´s voluntary movement, control of sitting and standing positions and walking abilities (Carlberg & Hadders-Algra, 2005). There are five classification levels and these are presented in *Appendix A*.

2.2 Postural Control in Children with Cerebral Palsy

2.2.1. Postural Control

Postural Control (PC) is the ability to regulate and maintain the body's position in space for stability or positioning and balancing the centre of gravity over the base of support (Pavão, Nunes, Santos, & Rocha, 2014). Postural control is classified as a component in the *International Classification of Functioning ,Health and Disability for Children and Youth (ICF-CY)* (WHO, 2011) within the activity and participation domain. It is included in the mobility charter and specifically, under the code *Changing and Maintaining Body Position* (d410-d429).

PC is a complex motor skills derived from the contribution of multiple sensorimotor processes, motor strategies and compensation mechanisms. Depending upon the processes that PC contributes too, it is defined as static (*static postural control*) or dynamic (*dynamic postural control*). However, the body requirements for every task are different and so the role of each system varies and is depending on these necessities.

Static PC is defined as the ability to maintain a stable body posture and orientation of the *Centre of Mass (CoM)* over the base of support (Sullivan & Portnry, 2014). Dynamic PC is defined as the ability to maintain body posture and orientation of the centre of mass over the base of support but while the body is in motion. Dynamic PC is more challenging for the human body and typically requires use of different motor strategies than the static PC (Bannister, 1969).

Bannister clearly described the body function requirements for static PC as follows (Bannister, 1996);

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(1) Strong lower limb and trunk muscles in order to sustain an erect standing posture (b730-b749 – Muscle Functions).

(2) Normal postural sensibility to receive information regarding body´s position.

(3) Typical function of the vestibular system to convey impulses for the position (b235 – Vestibular Functions).

(4) Higher centres should be active for maintaining the posture.

The essential mechanisms for dynamic PC (Bannister, 1996) are described as:

(1) Adequate muscle strength for the whole body to maintain balance and movement at the same time.

(2) Normal postural sensibility to receive information regarding movement (b780 – Sensations related to muscles and movement functions).

(3) Typical function of the vestibular system to convey impulses for the position in the environment and the movement (b235 – Vestibular Functions).

(4) Function of the central mechanism of coordination (cerebellum and basal ganglia.

(5) Active higher centers of controlling the voluntary/ ivoluntary maintenance of movement (b760 – Control of voluntary movement functions, b755 – Involuntary movement reaction functions, b765 – Ivoluntary Movement functions).

Postural orientation and *postural equilibrium* are the core functional goals for maintaining PC. *Postural orientation* includes the active control of the body positioning and tone against gravity and *postural equilibrium* is about the stabilization of the *Centre of Pressure (CoP)* through coordination of sensorimotor strategies, throughout voluntary but also externally generated disturbances in PC (Bannister, 1996). Centre of Pressure (CoP) sway is commonly used as a measure of the standing PC (Ruhe, Fejer, & Walker, 2011).

2.2.2. Postural Control in Children With CP

Children with CP respond abnormally to postural tasks and have limited postural activity (Rose, Wolff, Jones, Bloch, Oehlert & Gamble, 2002). The reason for this is the complex nature of impairments that are present in CP (Pavão, Nunes, Santos, & Rocha, 2014).

Specifically, children with CP do not have a stable base of support and their sensory feedback is poor, making is difficult to interpret and successfully undertake position corrections in space (Miller, 2007). Additionally, children with CP have impaired muscle coordination (rate

of agonist/antagonist co-activation) and an impaired ability to sequence the recruitment of motor components responsible for controlling posture (Pavão et al.,2014).

As a consequence, children often present with an increased CoP sway, something that negatively influences performance and functioning in everyday activities. The neuromotor deficits and biomechanical deviations that these children present with influence the control and orientation of their body parts within the limits of the support base (Roncesvalles, Woollacott, & Burtner, 2002). These compensations, can cause difficulties in controlling both static and dynamic PC and in performing *Activities of Daily Living (ADL)* (Pavão et al., 2014; Pavão, Santos, Oliveira, & Rocha, 2014; Rose et al., 2002; *)*.

Within the ICF, the health and motor status of the individual is defined as being dependent on multidimensional connections through a complex of health´s parts (WHO, 2011). Based on this fact, any change or impairment to the body structure and function (impairments in PC of children with CP for this study) is connected with the performance in *Activities of Daily Living* and participation (Dos Santos, Pavão, De Campos, & Rocha, 2012). Pavão et al. (2014) highlighted that a child's functional performance and level of independence are correlated with the CoP variables. Likewise, the impairments these children face in accomplishment of functional activities may be connected with restriction of participation in their environment (family environment, social context, school, out-school activities) and limit their performance in different postures (Pavão, Nunes, Santos, & Rocha, 2014).

2.2.3. Assessment Tools and Instruments For Postural Control.

Measures and the assessment tools for postural control can be linked to components of the International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY) and the Gross Motor Functional Classification System (GMFCS, Appendix 1) (Levitt, 2010). Some of the common and reliable tools used by healthcare professionals according to the research of are the *Pediatric Balance Scale (PBS)* (Franjoine,Gunther, & Taylor, 2003), *Timed up and Go (TUG) test* (Mathias, 1986), *Balance Evaluation Systems test* (BESTest; Horak et al., 2009, 2010), *Pediatric Evaluation of Disability Inventory (PEDI)* scores (Haley et al., 1992), *Biodex Balance System* (Hinman, 200), Trunk Control Motor Scale (TCMS) (Heyrman et al., 2011), *Stabilometry* (Kapteyn et al., 1983) and *Gross Motor Function Measure – 66 (GMFM-66)* (Russell et al., 2002). These are presented briefly in *Appendix B*.

2.3 Physical Therapy As an Intervention Method For The Management of PC In Children With CP

Physical Therapy (PT) is an intervention which promotes health and wellness through exercise and physical activity as well as other alternative methods. According to the WHO, *health* is defined as "a state of complete physical, mental and social well-being and not merely the absence of disease" and *wellness* as "the sense that one is living in a manner that permits the experience of consistent, balanced growth in the physical, spiritual, emotional, intellectual, social, and psychological dimensions of human existence." (Adams, Bezner & Steinhardt, 1997; WHO, 1948).

Physical therapists have an important role in specialized interdisciplinary services to help children with cerebral palsy (CP) reach their full potential in their family, educational, and community environments. As physical therapy belongs to pediatric rehabilitation, a multidisciplinary (MDT) approach is essential in order to achieve the tailor made goals for each child (Miller, 2007). Guralnick in the *Developmental Systems Approach* (DSA) stated that in order to have the best outcome from our intervention we need to consider the environment of the child and the levels of that according to Bronfenbrenner´s bioecological model of Development. We need to consider how the child will be benefit from our intervention to these environmental needs as the most significant purposes of PT interventions is to promote independence of the child (functionally and psychologically), to increase their participation in everyday activities and in general to enhance the quality of life of them and their families (Gunel, 2011).

An essential aspect of an effective intervention for physical therapists is to comprehend the family structure in which the child is included - family patterns of interaction (Guralnick, 2005; Bronfenbrenner,1994). In pediatric physical therapy collaboration with the family in decision making and goal setting is necessary to define the needs of the child to train the family to assist with physical therapy strategies which should be applied not only in clinical session but also in everyday living (Levitt, 2010).

In the set of impairments that children with CP are experiencing, PT includes methods for the management and promotion of PC (Sullivan, Schmitz & Fulk,2014). Findings in the literature (Levitt, 2010; Miller, 2007; Martin, 2006) highlight some common PT methods for management of PC and these are presented in Table 1.2. In a previously published systematic review (Dewar, Love, & Johnston, 2014), 13 interventions were identified as being used to address issues related to PC for children with CP. From these, 5 proved effective, 2 were ineffective and the remaining 6 were considered in need of more investigation

Table 1.2. Common PT Techniques For The Management of Postural Control (Levitt, 2010; Miller, 2007; Martin, 2006; Dewar et al., 2014)

Common PT Techniques For The Management of Postural Control
Neurodevelopmental Therapy/Bobath (NDT)
Advance Neuromotor Rehabilitation
Sensory Integration Therapy (SI)
Strengthening exercises/Kinesiotherapy
Functional Physical Therapy
Balance Interventions
Electrical stimulation Techniques
Recreational Therapy Methods (Hippotherapy, Aquatic Therapy)
Assistive Devices
Seating Systems
Movement Opportunities via Education (MOVE)
Pelvic Positioning

Interventions are constantly developing and the results of the previous systematic review (Dewar et al., 2014) concluded that there is a need of further research on this this topic in order to establish reliable and precis PC measures, to create dose guidelines and examine the possible efficacy of other intervention methods that have not been studied yet. As such, the purpose of this systematic review is to investigate the effective PT methods that were studied and experimented until now on CP children in order to provide to physical therapists with new evidence on the topic for integrating them in theirs intervention plans.

3. Aim Of The Systematic Review And Research Question

The purpose of this systematic literature review was to investigate which physical therapy methods are most effective for improving the postural control in children and adolescents diagnosed with CP, in order to provide to physical therapists with new evidence on the topic for integrating them in theirs intervention plans. Accordingly, the following research question was posed:

"What evidence exist regarding effective Physical Therapy Interventions for promoting postural control in children diagnosed with Cerebral Palsy?"

4.Method

4.1.Systematic literature review

In order to address the research question a systematic literature review was conducted in compliance with the principles and guidelines of Reporting Item for Systematic Reviews and Meta-Analyses (PRISMA). A systematic review is a review which has a very well-formulated research question and that uses methodical and clear methods to identify, collect, and critically assess relevant studies, and also to yield and analyse the data from them. Physical therapy is an intervention method and this systematic review is considered as a starting point for developing guidelines in clinical practice (The PRISMA Group 2009).

4.2.Search procedure

The literature search for this systematic review took place in March of 2019. Databases which were used to search for relevant studies included: PubMed, ProQuest, CINAHL, Web of science and Scopus. The search terms used were consistent across databases although the syntax was altered to account for difference in the search engines. An example of the search string used in PubMed is presented in *Appendix C*.

Additionally, reference lists of previous literature reviews on related topics were reviewed in order to identify more relevant articles. According to PRISMA flow diagram which is presented in *Appendix D* the research end up in the total number of articles which fulfilled all the inclusion criteria of the review (*Table 4.1.*).

4.3. Inclusion/exclusion criteria

In order to limit which studies to include in this review, inclusion and exclusion criteria were pre-determined. As the emphasis was on children with cerebral palsy and the effect of physiotherapy in facilitating postural control, only studies which investigated children diagnosed with CP were included. Articles were also required to have physiotherapy as an intervention and to include postural control as a primary or secondary outcome measure. Studies which did not present objective and clear measured results for postural control will be excluded. Articles were limited to the last decade (from 2015 until 2019) as a previous review has covered studies between and 2014. Studies were limited to those published in English and that were peer reviewed. Pilot studies, preliminary studies, literature reviews and case studies were excluded. The extraction protocol with inclusion and exclusion criteria is provided in *Table 4.1*.

Table 4.1. *Inclusion and exclusion criteria*

	Inclusion Criteria	Exclusion Criteria
Publication type	-Peer reviewed articles -Published in English -Free access articles	-non-scientific articles
Population	-Children diagnosed with CP -Age range 0-18	
Published Date	-Articles after 2013	
Intervention	-Physical therapy -Exercise Intervention	-Other Intervention than PT.
Outcome	-Postural control – Balance -Stability -CoP	-Irrelevant outcomes -PC mentioned in the outcomes but no measures.
Study Design	-Qualitative studies -Quantitative studies -Case-controlled studies -Case series -Case reports -Cohort studies -Randomized-controlled trials	-Pilot studies -Preliminary studies. -Case studies -Literature reviews

	-Non-randomized controlled trial -Quasi-experimental studies	

3.4 Screening procedure – title and abstract level

After duplicates were removed, the studies were screened on the basis of title and abstract, according to the inclusion and exclusion criteria, in order to conclude to the studies which remained for full text evaluation.

3.5 Selection process – full text

After reading the full text articles some of them were excluded because of design issues and because of lack of information. Consequently, we came up to the final number of articles (11) that were included in the quality assessment and data extraction processes.

4.4.Data extraction

The data extraction was completed using the protocol presented in Appendix 4. Information included in the protocol consisted of general information about each study (authors, title, publication date, aim, study design), information about the participants (diagnosis, exclusion criteria, age, n=, recruitment), intervention (type, frequency, duration, groups, setting, measures), results and conclusion.

4.5.Quality assessment

The quality assessment of the findings of the study was performed using the Joanna Briggs Institute Critical Appraisal tools for JBI Systematic (Gyi & Lockwood, 2011; Pearson, Wiechula, Court & Lockwood, 2005). There was only one evaluator who assessed the findings and came up with the final score for the included studies.

The articles were graded according to the questions on the JBI forms for the relevant study design. A high level of evidence was 13/13 for the randomized control trials, 10/10 for the case control study, 8/8 for the case report and 9/9 for the quasi-experimental studies. For each question symbols were used to represent "Yes", "No" and "Unclear". Studies which had more than three negative grades were excluded.

4.6.Data analysis

The data were analysed and synthesized according to intervention type.

5. Results

The initial search yielded 51 articles from PubMed, 20 from ProQuest, 9 from CINAHL, 2 from Web of Science and 11 from Scopus (total 93 articles). After reviewing the reference lists of previous literature reviews on related topics, 4 additional articles were identified and added making a total of 97 articles.

After duplicates were removed 88 studies remained to be reviewed on the basis of title and abstract. According to the inclusion and exclusion criteria 46 articles were excluded because they were published before 2014 , 18 articles had irrelevant topics and 4 did not meet the study design criteria. 20 full-text articles remained for evaluation. After reviewing the full texts, 4 articles were excluded because of design issues and 5 because of lack of information. 11 articles remained and were included for quality assessment and data extraction. The *PRISMA flow diagram* for this study and the reasons of exclusion in each stage is presented in *APPENDIX D* and an overview of the included articles is summarized in *Table 5.1* and the extracted data of them in *APPENDIX* E.

Table 5.1. *Overview of the included articles.*

Author	Title	Year
Ballington & Naidoo	The carry-over effect of an aquatic-based intervention in children with cerebral palsy.	2018
Bleyenheuft et al.	Intensive upper- and lower-extremity training for children with bilateral cerebral palsy: a quasi-randomized trial	2017
Bonnechere et al.	Balance improvement after physical therapy training using specially developed serious games for cerebral palsy children: preliminary results	2015
Duarte et al.	Effect of transcranial direct-current stimulation combined with treadmill training on balance and functional performance in children with cerebral palsy: a double-blind randomized controlled trial	2014

El-Basatiny & Abdel-aziem	Effect of backward walking training on postural balance in children with hemiparetic cerebral palsy: A randomized controlled study	2015
Emara	Effect of a new physical therapy concept on dynamic balance in children with spastic diplegic cerebral palsy	2015
Gatica-Rojas et al.	Does Nintendo Wii Balance Board improve standing balance? A randomized controlled trial in children with cerebral palsy	2017
Grecco et al.	Effect of a single session of transcranial direct-current stimulation on balance and spatiotemporal gait variables in children with cerebral palsy: A randomized sham-controlled study	2014
Lorentzen et al.	Twenty weeks of home-based interactive training of children with cerebral palsy improves functional abilities	2015
Song et al.	Effect of Horizontal Whole-Body Vibration Training on Trunk and Lower-Extremity Muscle Tone and Activation, Balance, and Gait in a Child with Cerebral Palsy	2018
Zarkou et al.	Stochastic resonance stimulation improves balance in children with cerebral palsy: a case control study	2018

5.1. Quality And Bias Assessment

The methodological quality scores of the included articles in this review are presented in tables in *APPENDIX G*.

From the Randomized Control Trials, four of them were found to have high level of evidence 13/13 as they fulfilled all the requirements of a randomized control trial(Duarte et al.,2014; El-Basatiny & Abdelaziem 2015; Gatica-Rojas et al.,2017; Grecco et al., 2014). One of the articles had moderate level of evidence 11/13 (Bleyenheuft et al., 2017) as it was unclear if the children and the intervenors were blind to the treatment. Two trials scored 10/13 and were considered as low level of evidence. One (Ballington & Naidoo, 2018) because was unclear if the intervenors and the assessors were blind to the treatment and it is not sure if the study has all the requirements from a randomized control trial fulfilled. In the other (Emara 2015) it is not mentioned if the participants, the intervenors and the assessors were blinded to the intervention.

The case control study (Zarkou et Al., 2018) scored 9 points out of 10 as it is not sure if the exposure period to the intervention was meaningful enough to come up to a conclusion.

The case report (Song et al.,) seemed to have a high level of evidence as it was collected 8 out of 8 points.

From the quasi-experimental studies, one scored 9 out of 9 points (Lorentzen et al., 2015), one 8/9 as there were no control group (Bayon et al., 2014) and the third one collected only 6 out of 9 points (Bonnechere et al., 2017) as the participants had not received any kind of comparison treatment and there were not a control group also.

5.2. Participants Characteristics

All of the studies included children with spastic CP but not all of them had the same type. The level of GMFCS ranged from I-III with only one study (Bleyenheuft et al., 2017) including level IV.

5.3. Physical Therapy Methods And Outcome Measures

From the 11 studies, 8 PT interventions aimed to managing postural control for children with CP. Standard PT was mostly used as an comparison to the experimental intervention. The results of the studies are analysed and grouped below based on the PT intervention used.

5.3.1 Electrical Stimulation Therapy

Three of the studies examined how electrical stimulation effects PC of the children with CP. The electrical stimulation methods applied were Transcranial Direct-Current Stimulation (tDCS) (n=2) and Stochastic Reasonance Stimulation (n=1).

Two studies (Duarte et al., 2014; Grecco et al., 2014) applied tDCS in children with spastic CP with GMFCS I-III to examine effects on balance. In the one study (Duarte et al., 2014) they combined it with treadmill training for 10 sessions (2 weeks) with an experimental and a control group .In the second study (Grecco et al., 2014) they performed only a single 20 minute session of tDCS also by two groups (experimental and control). Both studies evaluated static balance by analysing movement of *Centre of Pressure* (CoP) but in the first (Duarte et al., 2014) they also investigated dynamic balance (Pediatric Balance Scale-PBS) and functional performance (PEDI). The results related to postural control for both experimental groups were positive in the first post-T evaluation. Though, in both studies is was mentioned that the results of plain tDCS were not maintained, even 20 minutes after the session. The combination with another method such as treadmill training was preferable for the maintenance of effects.

One case control study investigated stochastic resonance (Zarkou et al., 2018) where authors compared the effects on balance of children with spastic diplegic CP and children with typical development. One session of subsensory SR stimulation was performed in muscles and

ligaments of the ankle joints. All the Centre Of Pressure (COP) components were measured for the assessment (centre of pressure velocity (COPV), centre of pressure confidence ellipse area (COPA) , Root mean square(RMS)) in anteroposterior (A/P) and medio-lateral (M/L) directions, in eyes closed and eyes open conditions. The results were much greater for children with CP as they decreased most of the components but the most significant difference between groups was in the eyes closed condition the COPV in M/L direction.

5.3.2. Aquatic Physical Therapy

Aquatic-based PT programmes use exercises or activities which are normally performed on land and transfer them to a pool environment. This is beneficial because the physical properties of the water allow initiation of movements for CP children and improve postural control. Only one article (Ballington & Naidoo, 2018) was identified as investigating aquatic PT. In this study the effects of the "10-point programme of Hallwick Concept" Were applied. The measurement tool for pre and post intervention was GMFM-66 which assesses not only the motor function but also quality of movement. Significant gains were noticed after the aquatic therapy. Though after a gap of one month the outcomes were reversed so the effects of the therapy were only short term.

5.3.3 Virtual Reality Therapy And Reactive Balance.

Physiotherapy using virtual reality technology is a relative new intervention and is becoming more popular. Virtual reality is a smart and popular tool in rehabilitation area as it allows for repetitive practice, feedback information, and motivation for endurance exercise (Lehrer, Chen, Duff & Rikakis, 2011). Three studies in this review (Gatica-Rojas et al., 2017; Lorentzen et al., 2015; Bonnechere et al., 2017) investigated how physiotherapy in combination with video games can enhance postural control in children with CP. The one of the studies examined a home-based reactive virtual training programme.

Two of the studies (Gatica-Rojas et al., 2017; Bonnechere et al., 2017) examined the effects of standard PT in combination with virtual games and Wii-therapy. In the first they had a control group who followed standard PT training and in the second the same intervention was used for all participants. A third study investigated a virtual home based interactive training programme used for 30 minutes every day over 20 weeks (Lorentzen et al., 2015).

The study group in the one study (Gatica-Rojas et al., 2017) exhibited greater results in the CoP sway than the control group. In the second study (Bonnechere et al., 2017) both static

and dynamic balance and also dynamic reaching were evaluated after the intervention. Significant improvements post-T were found only in static balance and not in dynamic balance or dynamic reaching.

In the trial where the home-based virtual reactive training programme was performed (Lorentzen et al., 2015) the results showed no significant differences in PC after the end of the sessions.

5.3.5 Standard Physiotherapy Combined with Other Methods

5.3.5.1 Standard Physiotherapy Combined With Backward Walking Training

In one of study (El-Basanity et al., 2015) backward walking training in combination with standard physical therapy techniques was applied in order to evaluate the effects in postural control of children hemiplegic CP in comparison with a group which received only the standard physical therapy part. The intervention consisted of 36 sessions (3 per week for 3 months). A Biotex Balance System was used as an assessment tool and there was a significant improvement in balance scores in both groups after the sessions but the experimental group had greater scores.

5.3.5.2 Standard Physiotherapy Combined With Horizontal Whole Body Vibration (WBV) training

Whole Body Vibration (WBV) training is the application of vibration sessions with the individual static standing on the vibration plate either performing dynamic movements . The components to vibration are frequency (number of complete cycles per second measured in Hertz), amplitude (the amount of displacement measured in mm) and the direction (the plate´s direction could be vertical or sinusoidal). The intensity of the vibration depends on the patient and is controlled through frequency and amplitude.

One case study, (Song et al., 2018) a child with spastic diplegic CP combined a standard PT programme with *Horizontal Whole Body Vibration* therapy on trunk for 2 months in total. Training consisted of range of motion exercises, trunk stability training, muscle tone facilitation exercises, weight-bearing exercises, and exercises for balance and everyday activities and WBV footplate with an amplitude of 30 mm in the anteroposterior direction and a frequency of 1–9 Hz . Static and dynamic balance were assessed using PDS and TUG test pre-T, post-T and follow up

(2 months). There was a significant improvement post-T for both components of balance, though in the follow-up evaluation the improvement in the static balance was not maintained.

5.3.5.3 Standard Physiotherapy Combined with Intensive upper- and lower-extremity training (HABIT-ILE)

HABIT-ILE is a hand-arm biomanual intensive therapy which includes lower extremity and postural control. Briefly, it is an approach which aims to enhance the performance in tasks where are needed for motor coordination and control of upper and lower extremities, using a problem-solving approach based on movement. One study (Bleyenheuft et al., 2017) compared this training method with a standard PT functional programme. After two weeks of intervention, the scores of the study group were greater in all the measures of PC post-T (GMFM-66, PBS, 6-minute walk test, ABILOCO-Kids) but in the control group there was no significant alteration.

5.3.5.4 Standard Physiotherapy Combined with Anti-gravity Treadmill Training

Antigravity treadmill training provides systematic and intense locomotor training and also produce brain neuroplasticity by walking on the treadmill where their weight is reduced up to 80% and so helps in maintaining their balance during movement (Azizi et al., 2017).

Emara and colleagues examined (2015) how this method, in combination with SPT, affected the PC of children with Spastic Diplegic CP, after 12 weeks of intervention . There was a control group that received only standard PT (n=15) and the control group which had the same standard PT therapy in combination with anti-gravity treadmill (n=15). The outcome that was measured was dynamic balance with the Biotex Balance Test in which the study group presented more significant improvement.

5.4 Ethical Considerations

When we are conducting research and especially involving paediatric populations, it is important to follow the ethical guidelines in order to reduce any potential to offend or harm any human being (Bee & Boyd, 2012). The *United Nations Convention on the Rights of the Child (UNCRC)* articles need to be considered also (Abebe & Bessell, 2014). Any kind of research or review, in this case in the medical sector, need to have as a goal to provide new evidence regarding the topic that is about and in this way to help professionals to improve the quality of their interventions in order to have better results. Consequently, the participants will be benefited from these as they would have more effective and developed interventions (Jahn, 2011).

As in this review the data have medical content they need to follow the standards of *the Declaration of Helsinki* which the *World Medical Association (WMA)* has developed as a statement of ethical principles for medical research involving human beings. The regional ethical committee supervises every ongoing study to confirm and approve that all the criteria are fulfilled (World Medical Association, 2013).All of the included studies in this paper contented all the ethical requirements as there were assessed either by the local Institutional Research Review Board, or the regional Ethics Committee.

6. Discussion

PC dysfunctions play a central role in the whole motor function and sometimes lead children with CP to spend more time in sitting position than in standing (Carlberg & Hadders-Algra, 2005). This could be a barrier to participate in their *Activities of Daily Living (ADL)* and performance of key activities (Pavão, Dos Santos, de Oliveira, & Rocha, 2014). Based on Guralnick´s Developmental system approach for early intervention (Guralnick, 2004) we could understand that these will cause a lot of stressors both to child and family. PT intervention is a way to promote child´s functional skills, so it could be a way to reduce the minimize the stressors and increase the quality of their life as the child´s body structure and function will be more controlled during tasks (Miller, 2007).

It has long been suggested that PT can enhance PC in children with CP (Campbell, 1990). In a previous systematic review, including studies published from 1980 until 2014 some exercise interventions they identified as having effective results, some that were still on investigation about their effectiveness and some that were proved ineffective (Dewar, Love, & Johnston, 2015). The present review examined data published from 2015 until 2019 in order to follow up on the previous review and to identify any new evidence.

In addition to interventions presented in the previous systematic review, 4 new interventions were identified in this systematic review. These were *aquatic physical therapy, backward walking training, intensive upper- and lower-extremity training (HABIT-ILE)* and *Whole Body Vibration (WBV) training*. 5 interventions established in the previous review were also identified in this review (*hippotherapy, hippotherapy stimulators, neurodevelopmental therapy (NDT)*, *progressive resistance exercise, upper-limb and trunk targeted exercise*). The common interventions that identified both in this and the previous systematic review are *electrical stimulation therapy, virtual reality therapy and treadmill training,*.

Particularly, the use of electrical stimulation with SDPT showed great scores in the PC but after the end of the sessions the improvement was not maintained. Additionally, the results shown that with the combination of standard PT the effects could be sustainable. This means that physical therapy sessions need to be integrated in the everyday life of children with CP in order to keep the results stable and see further enhancing in the PC.

The Aquatic Therapy proved to have a positive effect on PC but after one month without any intervention the results were not maintained. So as it is concluded in another review (Dimitrijevic, Bjelakovic, Lazovic, Stankovic, Colovic, Kocic & Zlatanović, 2012) permanent involvement in physical therapeutic activity is necessary for children with CP to ensure that their motor functions can be maintained at a higher level. This review can agree in this statement also.

Virtual reality therapy, which has become more popular the last decade, in combination with a typical PT programme can offer significant improvements in the static PC (Bonnechere et al., 2017) and in the CoP measures. It would be beneficial if this method could be investigated and developed further so it can have effects also in the dynamic PC. Also, in order to have better effects to each child the therapy need to be individualized and tailor made for every child so perhaps this is one of the reasons that the therapy has not always the same effects to the participants. Even though they have the same disability each case is unique and their needs differ so the physical therapist should consider this before the intervention plan (Yalcinkaya, Caglar, Tugcu, & Tonbaklar, 2014). The outcomes of virtual reality interventions on PC control seem to be positive but as it was highlighted in the previous review (Dewar, Love, & Johnston, 2015) this intervention should be additional to a standard physiotherapy session and not to replace it. Regarding the home based virtual serious games, there was a only slight difference in PC even though the intervention was intense. It is possible that the chosen exercises were not focusing in enhancing the PC as there were some positive outcomes in other body functions. It was suggested that the whole procedure may sometimes had implications so we can say that even though technology assists a lot the therapists field but should not be the only option in an intervention plan

Considering the results from this but also the previous systematic review (Dewar, Love, & Johnston, 2015) a standard PT programme in combination with some alternative PT methods could have positive effects for children with CP and their PC. Backward walking training , Horizontal whole body vibration training, Intensive upper- and lower-extremity training (HABIT-ILE) and antigravity treadmill training have proved beneficial for all the components of

balance. Apart from that, there is a need for more specific and detailed information for every PT intervention method as all of the included studies in this review seem quite generalized.

From the included studies 7 out of 11 had a control group, 1 had a comparison group with typical developing children and the remaining 3 were only experimental studies with no comparison or control group. For medical intervention experiments such as PT it is important to have a control group in order to compare difference between the results and to see that the intervention that we are studying is mainly the one that cause or not any change. The experimental and the study group though, should be as similar as possible in the characteristics (type of disability, GMFCS score, medication, age, gender) for the comparison to be more accurate.

Another significant parameter that we need to consider is that PC is classified to static and dynamic. In a research it is need to be clear in which one of them the intervention is focused, as there are different body and functional requirements for each one of them. Also, the participants´ impairment of PC should be clear to the researchers and similar between them to have consistency in the results.

It seems that as CP has different classifications it is not possible to generalize the physiotherapy interventions that are more effective for CP as each type of the classifications has different abnormalities and limitations. The combination of standard, conventional physical therapy, which is mainly consist of kinesiotherapy, neuromuscular facilitation, muscle strengthening or release, balance training, with other methods such as electrical stimulation, antigravity treadmill training , can have more sustainable results to the postural control.

However, the sessions should be a part of the everyday life as it is noticed at the post-treatment assessments, long-term the effects were not maintained. Most of physical therapy interventions of our results have proved reversible when the intervention sessions end and they performed a follow-up assessment. This fact is a great start for physical therapy professionals to plan programmes that the results in postural control will last long-term. The PT intervention is likely to be a part of everyday life for these children to have a stable and sustainable development of their PC. The *Chronic Care Model for Neurological Conditions (CCM-NC)* that is developed in Canada supports exactly this point about how people with neurological conditions such as CP will be offered with extra help for attend their interventions constantly in order to sustain healthier lives (Jaglal, Guilcher, Bereket, Kwan, Munce, Conklin … Riopelle, 2014).

6.1. Clinical Implications

Although this review presents evidence that PT intervention enhances the PC of children with CP no specific type of exercise intervention can be suggested more than the others. This is because each case is unique and the intervention needs to be adapted and tailored to the individual needs and characteristics of the child.

There are many things that can affect an intervention such as the possible medication the child takes, tolerance levels, obesity, the genetic characteristics, other movement impairments and also other intervention the child attends. While, the main goal will be enhancing the PC but it is clear that secondary goals need to be settled in order to reach this goal and also to promote the everyday functioning of the child. A more child-centered, holistic, interdisciplinary tactic in collaboration between family and the intervenors that assist them is recommended in order to have a better quality of interventions (Shonkoff & Meisels, 2000).

6.2. Limitations Of The Study

All the included studies should present the outcomes in PC only by presenting measured results. Some studies refer to PC but they do not provide measured results and they were excluded even if the intervention was beneficial for PC. The articles are limited to English language and availability in free full text and these may increase the risk of bias for important information to be missed by this limitation. Furthermore, although the search strategy appeared to target studies specifically focussed on the topic, it is possible that some significant studies were missed because the keywords were limited to title and abstract searches.

A number of differences between the studies regarding the treatment settings, treatment procedures, type of CP, measurement of PC may contribute at a point that there is no consistency in the results. As cerebral palsy has different classifications the results of this review are broad and it refers in general for CP, but obviously there are different needs in order to enhance the PC for each one of the classifications. This enabled the review to be open to a wide range of conceptualisations. However it could also be argued that without a clear classification the capacity to interpret the extracted data in this review was limited.

Additionally, both the research and the quality assessment of the data was done only from one researcher so there is a possibility of lacking some databases and articles and the risk of bias are more .

6.2 Future Research

More longitudinal studies are required in order to reveal how PT interventions effect PC after a longer period of time. Also studies for each classification and type of CP is necessary as specific limitations will be examined and the result will be more specific and accurate. The samples are still very small so the generalisability of the results could be doubted. Larger samples are strongly recommended for future research. Furthermore, the participants should have as many common characteristics in their PC and motor impairment as possible to give better quality and similarity to the results.

It would be interesting to try to combine more methods in a constant, stable programme in order to find the most appropriate PT modalities that enhancing the PC. Moreover, researches the separate the plan for dynamic and static postural control could offer a lot of information and also give the therapists an idea about how they could approach this in order to have positive effects in both at the same time.

7. Conclusion

According to the results of this systematic review we can conclude that there are many PT intervention methods that enhance PC in children with CP. It seems that is necessary for these children to integrate PT intervention in a regular and stable way in order for the positive effects in their PC to be maintained and last long-term. It is important that researchers investigate more this topic as CP has different classifications and in combination with the individual characteristics of each child we need to have more detailed information about the methods, the duration and the intensity of the PT programme and also larger samples. Medical sciences and interventions are developing constantly, so this creates a need to investigate new intervention methods and also to combine them with the old ones in order to achieve a better outcomes.

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9. APPENDIX

9.1. Appendix A

Palisano et al., 2007.Retrieved from CanChild

Gross Motor Functional Classification System (GMFCS)
LEVEL I – Walking without limitations
LEVEL II – Walks with limitations
LEVEL III – Walks using a hand-held mobility device
LEVEL IV – Self-Mobility with limitations may use powered mobility
LEVEL V – Transport in a manual wheelchair

9.2. Appendix B

Common Assessment Tools For Postural Control/Balance

Tools	Description
1. Pediatric Balance Scale (Franjoine, Gunther, & Taylor, 2003)	**14 item functional activities** (sitting, standing, postural transitions) to be rated by assessors. Each item scored from 0-4 (total maximum score56). A total less than 45 points indicates high risk of falling.
2.Timed Up and Go (TUG) test (Mathias 1986)	**The test is a functional task:** From sitting in a chair stand up, walk 3 m., turn around and walk back to sit down. A stop-watch is measuring the time until the task is completed and if it is more than 3 min. the child is at high risk for falling (poor postural control).

3. Balance Evaluation Systems test (BESTest; Horak et al., 2009, 2010)	**36 Items in 6 Groups:** Biomechanical Constraints, Stability Limits/Verticality, Anticipatory Postural Adjustments, Postural Responses, Sensory Orientation and Stability in Gait. Each item scored on a 4-level ordinal scale (0=worst, 3=best). Total test´s results provided as a percentage of the total score.
4. Pediatric Evaluation of Disability Inventory (PEDI) scores (Haley et al., 1992)	Questionnaire which consist of 3 parts (self-care, mobility and social function) for caregivers mostly who can provide information for child´s performance in daily tasks, routines and activities. Scores: 0=unable to perform the activity, 1=activity is part of the child´s abilities.
5. Biodex Balance System (Hinman, 2000)	Try to maintain standing balance on a moving platform where the amount of stiffness controlled mechanically. A LCD screen shows where COM is in relation to the periphery of the platform.
6. Trunk Control Motor Scale (TCMS) (Heyrman et al., 2011)	This is a 15-item scale which evaluates sitting balance during the implementation of different functional activities. Sitting balance, dynamic balance and reaching balance are scored with a total score of 58 points.
7. Stabilometry (Kapteyn et al., 1983)	Stabilometry is a valid and objective evaluation method of the still, upright stance posture. The properties of the postural sway are measured through a force plate in an vertical standing position.
8. Gross Motor Function Measure – 66 (GMFM-66) (Russell et al., 2002)	The Gross Motor Function Measure – 66 (GMFM-66) is an 66-item evaluative score sheet tool of motor function designed for

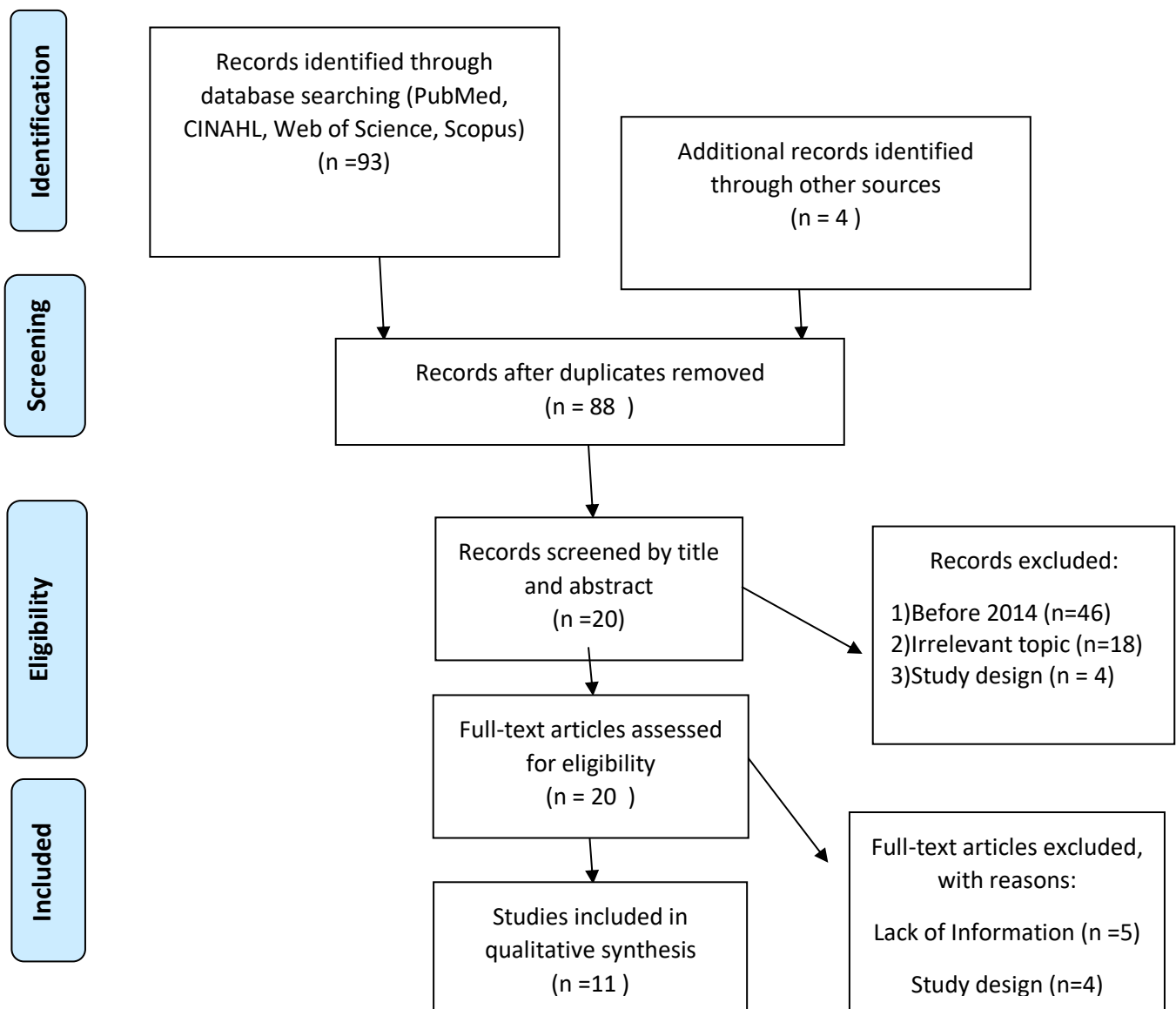|	measuring changes in the gross motor abilities of children with cerebral palsy.

9.3. Appendix C

Search terms in PubMed

((((((cerebral palsy[Title/Abstract] OR "cerebral palsy"[MeSH Terms]) OR cp[Title/Abstract]) OR spastic quadriplegic cerebral palsy[Title/Abstract]) OR spastic quadriplegia[Title/Abstract]) AND ((((((((((((((("physical therapy modalities"[MeSH Terms] OR "exercise therapy"[MeSH Terms]) OR "rehabilitation"[MeSH Terms]) OR physiotherapy[Title/Abstract]) OR physical therapy[Title/Abstract]) OR rehabilitation[Title/Abstract]) OR exercise therapy[Title/Abstract]) OR muscle strengthening[Title/Abstract]) OR motion therapy[Title/Abstract]) OR balance exercise[Title/Abstract]) OR stability exercise[Title/Abstract]) OR sensory motor integration[Title/Abstract]) OR neuromuscular facilitation[Title/Abstract]) OR therapeutic exercise[Title/Abstract]) OR motor rehabilitation[Title/Abstract]) OR physical activity[Title/Abstract]) OR exercise intervention[Title/Abstract]) OR pediatric physical therapy[Title/Abstract])) AND (((((((((((posture[Title/Abstract] OR postural control[Title/Abstract]) OR postural balance[Title/Abstract]) OR postural stability[Title/Abstract]) OR postural[Title/Abstract]) OR postural performance[Title/Abstract]) OR postural sway[Title/Abstract]) OR proprioception[Title/Abstract]) OR postural orientation[Title/Abstract]) OR postural activity[Title/Abstract]) OR posture development[Title/Abstract]) OR "postural balance"[MeSH Terms]) OR "proprioception"[MeSH Terms]) AND ("loattrfree full text"[sb] AND "2009/03/09"[PDat] : "2019/03/06"[PDat] AND English[lang] AND ("infant"[MeSH Terms] OR "child"[MeSH Terms] OR "adolescent"[MeSH Terms]))

9.4. APPENDIX D

PRISMA flow diagram

Identification

Records identified through database searching (PubMed, CINAHL, Web of Science, Scopus)
(n =93)

Additional records identified through other sources
(n = 4)

Screening

Records after duplicates removed
(n = 88)

Eligibility

Records screened by title and abstract
(n =20)

Records excluded:

1)Before 2014 (n=46)
2)Irrelevant topic (n=18)
3)Study design (n = 4)

Full-text articles assessed for eligibility
(n = 20)

Included

Full-text articles excluded, with reasons:

Lack of Information (n =5)

Study design (n=4)

Studies included in qualitative synthesis
(n =11)

9.5. APPENDIX E

Extraction protocol

General Information	Authors Title Year Journal
Study Purpose and Design	Aim Study Design
Sample-Participants characteristics	Diagnosis Exclusion criteria Age N= Recruitment
Intervention	Type Frequency Duration Groups Setting Outcome Measures
Results	
Conclusion	

9.6. APPENDIX F

Summarized Extraction Of The Results

Trial	Design, Level of Evidence	Intervention	Participants	Outcome Measures Evaluation Frequency	Results
Virtual Reality					
Gatica-Rojas et al., 2017,	13/13	EG: Wii Therapy CG: Standard PT (stretching, flexibility, strengthening, and balance exercises for 40 minutes) 3 per week (6 weeks,18 seessions)	n=32 SDCP,SHCP GMFCS I or II 7-14 years	Centre of pressure sway (CoPsway) (Standing balance)	The Wii-therapy group exhibited better balance than the SPT group, with a significantly decreased CoPSway and SDAP only under the EO condition.
Lorentzen et al., 2015	9/9	Server-based interactive training-system using flash-technology at home 30 minutes session (every day for 20 weeks)	n=34 SCP GMFCS I-II 9-16 years	Balance: Romberg 30 s, eyes open (pre-T, post-T, post-T2 12 weeks after)	No significant interaction effect for the training/control group and pre training/post training was found for any of the Romberg tests of the children.
Bonnechere et al., 2017	6/9	Five specific video games controlled with a Nintendo Wii Balance Board (continue their SPT programme) 1 per week (4 weeks, 4 sessions)	n=10 SCP GMFCS I-III 5-15 years	-Static Sitting balance -Dynamic Sitting Balance, dynamic reaching: Trunk Control Motor Scale (TCMS) before & after every session	Significant improvements were found for static sitting only post-T, but no difference in dynamic sitting balance and dynamic reaching.
Electrical Stimulation					
Grecco et. Al., 2014	13/13	SG:Active transcranial direct-current	n=20 CP 6-10 years	**Static Balance-** Stabilometric	

		stimulation (tDCS) CG: Placebo tDCS		analysis on a force plate (Pre-T, Post-T, Post-T 20 min.)	
Duarte et al., 2014		SG: gait treadmill training and tDCS (active) CG: gait treadmill training and tDCS (placebo) 5 per week (2 weeks,10 sessions)	n=24 Spastic CP GMFCS I,II,III 5-10 years	**Static Balance**- Stabilometric analysis on a force plate **Functional Balance**- PBS **Functional Performance**-PEDI (one week before, one week after, one month after	PBS: Active Group increased scores but placebo group had no significant difference pre-T and post-T scores.
Zarkou et al., 2018	7/9	One session of Stohastic Reasonance Electic Stimulation	n=20 10=SDCP 10=TD children GMFCS I,II,III 6-18 years	the centre of pressure velocity (COPV) in anteroposterio r (A/P) and medial-lateral (M/L) direction, 95% COP confidence ellipse area (COPA), and A/P and M/L root mean square (RMS) measures were computed and compared to access the balance.	CP group: decreased COPV in A/P direction, and COPA measures for the eyes open condition. Decreased COPV only in M/L direction in the eyes closed condition, SR significantly. Greater reduction in all the COP measures but the RMS in M/L direction during the eyes open condition compared to their TD peers. The only significant difference between

					groups in the eyes closed condition was in the COPV in M/L direction.
Aquatic Physical Therapy					
Ballington & Naidoo, 2018	10/13	SG: aquatic sessions (The 10-point programme of the Halliwick Concept) 2 per week, 30 min, 8 weeks CG: normal activities **Shift between the groups after week 8**	n=10 CP GMFCS I-III 8-12 years	GMFM-66 : changes in gross motor function	The intervention group's post-intervention score increased more (z = -2.803, p = 0.005) than the control group's score. The wash-out period was long enough for the effect from the intervention not to be carried over when the groups crossed over. Therefore, the positive effects of the intervention were only short-term.
Standard Physiotherapy In Combination With Other Methods					
Bleyenheuft et al., 2017	11/13	SG: SDPT + HABIT-ILE (2-day training session) CG: SDPT (NDT, functional training, occupational therapy)	n=20 bilateral CP GMFCS II-IV 6-16 years	Lower extremity and postural control: GMFM-66, 6-minute walk test, PBS, ABILOCO Kids	Significant higher results at the study group in all the measures of PC post-T. No important difference were found at the control group results.

El-Basanity et al., 2015		CG: SDPT (60 min.) SG: SDPT (60 min.) + backward walking training (25 min.) 3 per week (12 weeks,36 sessions)	n=30 SHCP 10-14 years	Postural Balance-Biotex Balance System	
Emara et al., 2015	10/13	CG: SDPT (1 hour) SG: SDPT (1 hour) +20 minutes gait training with antigravity treadmill 3 per week(12 weeks, 36 sessions)	n=30 SDCP 6-8 years	Dynamic Balance: Biotex Balance System	Significant improvements of dynamic balance for both groups but mostly in the study group.
Song et al., 2018	8/8	SDPT (3 per week,8 weeks 30 min.) + horizontal WBV training (3 per week, 4 weeks, 20 min.)	n=1 SDCP 10 years	Static and dynamic balance ability: Pediatric Balance Scale (PBS) and Timed Up and Go (TUG) test	The PDS and TUG test showed greater improvement after horizontal WBV training.

SG= study group, CG= control group

9.7. APPENDIX G

Quality Assessment Tables

1. Randomized Control Trials Quality Assessment

Randomized Control Trial ● Yes ✖ No ¤ Unclear	Ballington & Naidoo, 2018	Bleyenheuft et Al., 2017	Duarte et.Al, 2014	El-Basatiny & Abdel-aziem 2015	Emara 2015	Gatica-Rojas et Al., 2017	Grecco et Al., 2014
1. Was true randomization used for assignment of participants to treatment groups?	✔	✔	✔	✔	✔	✔	✔
2. Was allocation to treatment groups concealed?	✔	✔	✔	✔	✔	✔	✔
3. Were treatment groups similar at the baseline?	✔	✔	✔	✔	✔	✔	✔
4. Were participants blind to treatment assignment?	✔	¤	✔	✔	¤	✔	✔
5. Were those delivering treatment blind to treatment assignment?	¤	¤	✔	✔	¤	✔	✔
6. Were outcomes assessors blind to treatment assignment?	¤	✔	✔	✔	¤	✔	✔
7. Were treatment groups treated identically other than the intervention of interest?	✔	✔	✔	✔	✔	✔	✔
8. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	✔	✔	✔	✔	✔	✔	✔
9. Were participants analyzed in the groups to which they were randomized?	✔	✔	✔	✔	✔	✔	✔
10. Were outcomes measured in the same way for treatment groups?	✔	✔	✔	✔	✔	✔	✔
11. Were outcomes measured in a reliable way?	✔	✔	✔	✔	✔	✔	✔
12. Was appropriate statistical analysis used?	✔	✔	✔	✔	✔	✔	✔

13. Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?	¤	✓	✓	✓	✓	✓	✓

2. Case Control Study Quality Assessment

Case Control Study ● Yes ✗ No ¤ Unclear	Zarkou et Al., 2018
1. Were the groups comparable other than the presence of disease in cases or the absence of disease in controls?	✓
2. Were cases and controls matched appropriately?	✓
3. Were the same criteria used for identification of cases and controls?	
4. Was exposure measured in a standard, valid and reliable way?	✓
5. Was exposure measured in the same way for cases and controls?	✓
6. Were confounding factors identified?	✓
7. Were strategies to deal with confounding factors stated?	✓
8. Were outcomes assessed in a standard, valid and reliable way for cases and controls?	✓
9. Was the exposure period of interest long enough to be meaningful?	✗
10. Was appropriate statistical analysis used?	✓

3. Case Report Quality Assessment

Case Report ● Yes ✗ No ¤ Unclear	Song et Al., 2018
1. Were patient's demographic characteristics clearly described?	✓
2. Was the patient's history clearly described and presented as a timeline?	✓
3. Was the current clinical condition of the patient on presentation clearly described?	✓
4. Were diagnostic tests or assessment methods and the results clearly described?	✓
5. Was the intervention(s) or treatment procedure(s) clearly described?	✓
6. Was the post-intervention clinical condition clearly described?	✓
7. Were adverse events (harms) or unanticipated events identified and described?	✓
8. Does the case report provide takeaway lessons?	✓

4. Quasi-Experimental Studies Quality Assessment

Quasi-Experimental Studies ● Yes ✗ No ¤ Unclear	Bayon et Al., 2014	Lorentzen et Al., 2015	Bonnechere wt Al., 2017
1. Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)?	✓	✓	✓
2. Were the participants included in any comparisons similar?	✓	✓	✗
3. Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	✓	✓	✗
4. Was there a control group?	✗	✓	✗
5. Were there multiple measurements of the outcome both pre and post the intervention/exposure?	✓	✓	✓
6. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	✓	✓	✓
7. Were the outcomes of participants included in any comparisons measured in the same way?	✓	✓	✓
8. Were outcomes measured in a reliable way?	✓	✓	✓
9. Was appropriate statistical analysis used?	✓	✓	✓