Therapeutic Interventions for trunk and improvement of posture in children with cerebral palsy: A Review of the Literature

1. Abstract

Background: Cerebral Palsy (CP) is associated with disorders of movement, posture and intellectual activities which are due to a non-progressive lesion or damage to the immature brain and can be range from mild to profound.

Objective: The aim of this literature review is to investigate and analyze the effectiveness of four new – in the last twenty years - modern therapeutic interventions (Hippotherapy, Virtual Reality, Aquatic Therapy and Adeli Suit Therapy) in the trunk and improvement of posture in children with cerebral palsy.

Methods: After searching databases like Pubmed, Science Direct, Medline, Pedro, QMU e-Library and Cochrane Library for the period of 1995 to 2015, the total of 250 papers were retrieved. The studies consisted of children of all ages, diagnosed with CP. Only 73 of the studies were meeting the inclusion criteria.

Results: Forty-four trials were indentified. Four intervention categories were distinguished (virtual reality therapy, hippotherapy, aquatic therapy and Adeli or Thera suit therapy). The results showed that each of the four therapies analyzed

can be effective in improving trunk control and posture with or without additional physical therapy. However, further research is needed due to the diversity among types and severity of CP.

Conclusion: Aquatic Therapy, Hippotherapy, Virtual Reality and Adeli/Thera Suit showed efficiency in treatment programs of children with CP. Future research studies must accommodate the effectiveness of these techniques and should improve the ability to target them at community and family levels.

Key words: Cerebral Palsy, Adeli Suit Treatment, Thera Suit, Hippotherapy, Virtual Reality, Aquatic Therapy, Hydrotherapy

Abbreviations: Cerebral Palsy (CP), Virtual Reality (VR), Quality of Life (QoL), Trunk Control Measurement Scale (TCMS), Gross Motor Function Measures (GMFM 66,88), Pediatric Balance Scale (PBS), Neurodevelopmental Treatment (NDT), Mechanical Efficiency Index (EI_{HB}), Pediatric Evaluation of Disability Inventory (PEDI) - Functional Status Score (PEDI-FSS), Water Orientation Test Alyn 2 (WOTA2), Modified Ashworth Scale (MAS), Canadian Occupational Performance Measure (COPM), Movement Assessments Battery for Children (M-ABC), Pictorial Scale of Perceived Competence and Social Acceptance (PSPCSA), Electromyography (EMG) – surface EMG ($_S$EMG), Aquatic Independence Measure (AIM), Gross Motor Function Classification System (GMFCS), Perceived Physical and Social Competence (PCC), Sitting Assessment Scale (SAS), Balance Performance Monitor (BPM), Double-Leg Stance (DLS), One-Leg Stance (OLS), vertical Ground Reaction Force (vGRF), Rate of Force Development (RFD), Video Motion Capture (VMC), Abductor

Muscle Symmetry (AMS), Bruininks-Oseretsky Test of Motor Proficiency (BOMTP), home-based Virtual Cycling Training (hVCT)

2. Introduction

Cerebral Palsy (CP) is defined as static encephalopathy due to brain injury before the full development of the cerebrum (Krigger 2006). Owing to the development of the brain in the first two years of life, CP can occur at birth or in early childhood and insist throughout the individuals' life (Abbskhanian et al. 2015). About 70%-80% cases are referred in the prenatal period and with no obvious cause (Krigger 2006). CP is a non progressive motor impairment influencing the physical and often intellectual activity of the patients (Kruse et al. 2009). The two categories that CP is classified are by type of movement disorder and by anatomic distribution. In CP the most frequent movement pattern is spastic whereas dyskinetic, hypotonic, ataxic and mixed form movement patterns are more seldom (Alexander & Matthews 2010).

CP is the most frequent motor disability in childhood and as a result the prevalence of CP is estimated at about 3,6 per 1000 in children going to school (Alexander & Matthews 2010). Severe CP can be associated with a reduced life expectancy (NICE 2014). As the person with CP develops, the clinical picture changes and is characterized by brain lesions even when CP is not progressive (Alexander & Matthews 2010). Thus, CP brings in numerous problems that affect

the whole individual such as significant musculoskeletal and movement disorders. These are presented in Appendix 1.

More specifically for trunk and posture disorders, activities like reaching and walking activate the truck which should remain a stable base of support during execution of upper or lower limb movements (Heyrman et.al. 2011). Therefore, poor trunk control has direct influence in daily activities like sitting and it is one of the primary problems in children with CP (Saether et.al. 2015). Postural control is related to stability and orientation, characteristics of the need the body has to maintain its position in space (Massion, 1998 cited in Harris & Roxborough 2005). Hence, posture control deficit is a restricting factor in children with CP (Pavao et.al. 2014). Additionally, the characteristic of spasticity can cause difficulties in postural control (Temcharoensuk et al. 2015).

As for the quality of life (QoL), children with CP seem to face lower QoL because of the limited participation in social or leisure activities and the restrictions in mobility (Alexander & Matthews 2010). However, some findings show that children with CP have the potential to live and develop as all children of their age without any difficulty (Dickinson et.al. 2007). Children and young people with mild CP have higher diversity and lower intensity of overall participation than those with severe CP (Orlin et al. 2009).

Physiotherapists as health professionals in the management of children with CP acquire a pivotal role which aims to restore the function, movement and optimal use of the child's potential and to give instructions to the child's parents on how to handle them at home (Antilla et al. 2008). Therapy for children with CP has aims to meliorate the QoL for the family and the person with CP (Mayston

2001). Some of the commonest therapeutic approaches being used in the rehabilitation of children with CP, that show effectiveness in preceding studies are NDT, conductive education, strength training, orthotic devises (Abbskhanian et al. 2015) and PNF (Mayston 2001).

Specifically, therapies which have gained recognition in the last years and seem to be more effective in trunk stability and posture are compared to more conventional therapies. For example, Aquatic Therapy and the aquatic programs consist of the Halliwick method, Ai Chi, Watsu, Feldenkrais and other programs depending on each case (Henley & Wollam 2009). Aquatic therapy or hydrotherapy often used as a term until 2008 is an aquatic program utilising the properties of water in order to improve function in a specially constructed and suitably heated hydrotherapy pool (Bryant et al. 2009). One of the benefits of water is buoyancy which decreases the influence of gravity and increases postural support of children with CP (Kelly & Darrah 2005). Also, hippotherapy and the rationale behind hippotherapy is to mimic human gait patterns with the movement and gait of the horse. This has immediate effects on the rider's body because of the accurate, mild, rhythmic and repetitive movement. The effectiveness of hippotherapy is attributed to the mending of balance, posture, coordination, muscle strength and psychological effects (Zadnikar & Kastrin 2011).

Virtual Reality (VR) rehabilitation which, is defined as “the use of interactive simulations created with computer hardware and software to present users with opportunities to engage in environments that appear to be and feel similar to real world objects and events” (Khayatzadeh Mahani et.al. 2012).

Multimodal environments are a beneficial method of VR for rehabilitation treatment because of the advanced ongoing recalculation of the sensory inputs that would lead to suitable improvements of posture in a realistic context ambient (Sveistrup 2004). Bonnechere et al. (2015) also observed efficacy in posture in children with CP.

Adeli or Thera suit Therapy is also used in CP patients. The Adeli suit is substantially a system of supporting elements composed of a special vest, shorts, knee caps, and footwear. Each pair of the supporting units is connected with a set of adjustable elastic ties called “Bungee” (Khayatzadeh Mahani et.al. 2011). This therapy has four stages (Turner 2006). Some of the benefits of this approach are improvement of coordination by decreasing spasticity, balance improvement and readjusting the body in the right position (Alagesan & Shetty 2010).

Since, there have been no other studies from the past decades that have discussed the efficiency of the four interventions on trunk and posture control in children with CP, a literature review is required to summarize the effects of each intervention. Therefore, the purpose of this literature review is to analyze and assess the efficiency of the four interventions and find the most effective in trunk and posture control of children with CP.

3. Methods

3.1. Literature Searches

A search of the literature was carried out in order to acknowledge the appropriate articles. The databases that were searched consisted of: Pubmed, Science Direct, Medline, PEDro, the Cochrane library and the QMU e-Library from 1995 to 2015. The reference lists of the identified studies and reviews were examined for further references.

3.2. Inclusion Criteria

The components examined for the inclusion of articles in this review are: 1. the type of study, studies published in peer reviewed journals, full-length articles (RCT`s, clinical trials and case reports) since 1995, 2. the population, the participants have to be children or adolescents diagnosed with CP between the age of 3 and 18 years old. 3. the interventions that the studies use have to be clinically plausible physiotherapeutic interventions or a combination of these and 4. the only language that is being used is English.

3.3. Exclusion Criteria

Surgical and pharmaceutical interventions, acupuncture and hyperbaric oxygen therapy were excluded from this literature review. In addition, if the age limits and the condition did not comply with the criteria, the articles were excluded. Lastly, articles with different languages other than English were excluded.

3.4. Assessment of Methodological Quality

The Pedro scale was used in order to evaluate the methodological quality of half of the articles in this review. The methodological quality of RCT`s and quasi-RCT`s are measured by this scale which is a tool developed for the

measurement of this trials in physiotherapy (Maher et al. 2003). The Pedro scale includes 11 items: 1) inclusion criteria & source, 2) random allocation, 3) concealed allocation, 4) baseline comparability, 5) blind subjects, 6) blind therapists, 7) blind assessors, 8) adequate follow-up, 9) intention to treat, 10) between groups comparison, 11) point estimates & variability. This scale was scored for the total of 10 points as the first item is related to external validity (Foley et al. 2006). The use of Pedro scale is a valid tool for assessing methodological quality (de Morton 2009). Even if the validity of the Pedro scale has not been fully investigated, the reliability of this scale has been widely tested. Acceptable, good reliability (Macedo et al. 2010) and sufficient reliability (Maher et al. 2003) was found in these studies when using the Pedro scale. However, further studies are needed to evaluate the validity and reliability of this tool.

3.5. Data Synthesis Methods

The literature review showed a variety of studies with different patient types, severity of CP, treatments (type, frequency and duration) and outcome measures. This resulted in a diverse presentation of results. In this review, the interventions were grouped and analyzed separately. The outcomes measures included trunk and posture control, balance and function. The results were analyzed in the discussion according to the presence of statistically significant differences in the studies and in every therapeutic approach and the effectiveness of the groups that presented according to outcome measures.

4. Results

The database research found 250 citations, of which 73 full text articles were used for evaluation (Appendix 2). Forty four articles (44) fulfilled all inclusion

criteria, of which 17 were RCT`s, 7 were case reports, 16 were clinical trials and 4 were pilot studies.

4.1. Methodological Quality

The methodological quality scores of the studies are presented in Appendices 3-6. The articles that used the four therapies are mostly RCT`s and clinical trials and they were evaluated by the Pedro scale. More specifically, for VR therapy there were four RCT`s of which the highest was scored at 7/10 (Lazzari et al. 2015), the lowest at 4/10 (Deepak et al. 2012) (Reid & Campbell 2006) and one was scores at 5/10 (Chen et al. 2012). In hippotherapy, the highest score was 8/10 (Herrero et al. 2012), another study follows with 7/10 (McGibbon et al. 2009). Moreover, two researches scored 5/10 (Benda et al. 2003) (Davis et al. 2009) and the final two have 4/10 (Lee et al. 2014) (El-Meniawy & Thabet 2012). For aquatic therapy, four RCT`s analyzed scored at higher than 7/10 (Hiller et al. 2010), another study at 6/10 (Chrysagis et al. 2009) and two studies at 5/10 (Olama et al. 2015) (Dimitrijevic et al. 2012). Lastly, for the Adeli/Thera Suit therapy four RCT`s, scored 7/10 (Bailes et al. 2011) which was the greatest result. The lowest score was 4/10 (Alagesan & Shetty 2010). In the middle were two studies with scores of 6/10 (Kim et al. 2015) (Khayatzadeh Mahani et al. 2011).

As mentioned above, all articles and particularly RCT`s are validated by the Pedro score that they yield. The higher the score, the more acceptable and useful the article can be. It is observed that in a total of 17 articles 5 articles were of high methodological quality (scoring at 7/10 and 8/10), 8 articles were of

medium methodological quality (scoring at 6/10 and 5/10). The other 4 articles were of poor methodological quality scoring at 4/10.

5. Discussion

5.1. Aquatic Therapy

Aquatic therapy is the oldest approach of the four presented. This has led to more studies of this technique. Studies that have been included report only a beneficial effect in a wide range of problems in children with CP. A lot of studies were excluded due to non compliance of the criteria. All of the studies have a plethora of outcome measures. The most common was the GMFM (66, 88) scale, followed by the WOTA2, PEDI, AIM, MAS and Goniometer which are observed in almost all studies. The more rare scales were the PCC, M-ABC, PSPCSA and COPM. The analysis of the studies will be mainly driven by the outcome measures.

As mentioned, an applied swimming program in children with CP has revealed statistically significant effect on the improvement of GMF which includes sitting and standing movements. In a pilot study differences were observed in GMFM-88 and WOTA in only one group of participants. Similar results are seen in three other studies with the same outcome measures including the MAS and the Goniometer. However, these studies are more reliable due to the existence and comparison of control groups. In more detail, GMF skills on land and aquatic abilities show improvement after a 6 week aquatic intervention program in CP children (Dimitrijevic et

al. 2012) and aquatic therapy can also be helpful and yield positive results in children with poor GMFCS level (Lai et al. 2014). According to Chrysagis et al. (2009), one thing that can be added is the possible positive effects on ROM and spasticity which are two factors that directly depend on trunk and posture.

The next study is based on a case report where after 12 weeks of aquatic therapy the results in COPM and GMFM-66 scales showed statistically significant improvement (Retarekar et al. 2009). Based on different scales (M-ABC & PSPCSA) and with two groups evaluated, aquatic therapy seems to be a feasible intervention and improves GMF skills in children with CP (Hiller et al. 2010). In contrast to all the other studies, only one examined the combination of aquatic and exercise therapy. The results by EMG and electrogomiometer suggest decrease on spasticity and H-reflex, two factors that disturb the posture of children with CP (Olama et al. 2015). The last two studies were conducted by the same author, but examined different variables. The first study had no control group, it expressed waters` strong relationship to motor performance (sitting, standing, balance) as measured by GMFM, PEDI and AIM (Getz et al. 2006). The second study used a control group. The results were therefore more reliable. Positive effects on PEDI, AIM and PCC were reported (Getz et al. 2007).

Limitations & Further Studies

Despite the positive effects of aquatic therapy all studies contained several limitations such as the use of small samples and samples of

convenience. This resulted in limited generalizability. The next restrictions were the time duration of the therapy and the lack of randomization and blinding. The last limitation was seen in only one article in which there was no control group. The above limitations lead to decreased validity of these articles. Finally, it was noted that two studies had no restrictions. Table 3 below shows the information of all articles in more detail. Further studies are required to evaluate this approach.

Table 1

Study	Study Design	Sample	Sample Groups	Treatment Time	Outcome Measures	Results	Conclusion
Jorgic et al. 2012	Pilot Study	7 children	-	45`, 2 days/wk, 6 weeks	GMFM-88 WOTA2	(p<0,001) in dimension E & total score T of GMFM & (p<0,001) in overall results in WTO of the WOTA2	Statistically significant change on development the overall GMF of children with CP after the swimming program.
Lai et al. 2014	Clinical Trial	24 children	11 children in PATG 13 children in CG	1h, 2 days/wk, 12 weeks	GMFM-66 MAS	(p<0,001) in GMFM-66 and MAS in PATG in post-treatment	CP children (included those with poor GMFCS) can benefit of an alternative therapy like, pediatric aquatic therapy.
Chrysagis et al. 2009	RCT	12 children	6 children in EXPG 6 children in CG	45', 2 days/wk, 10 weeks	GMFM-66 MAS Goniometer	(p<0,001) in GMFM-66 in EXPG (p>0,05) in ROM in both groups (p<0,001) in spasticity in EXPG	An aquatic program might have a positive effect in GMF as well as in ROM and spasticity in students with spastic CP.

Getz et al. 2006, in press	Clinical Trial	49 children	-	30`, 40 sessions, 5 months	AIM PEDI GMFM GMFCS	(p<0,001) between the total AIM & GMFM scores, as well as in PEDI self-care and mobility scores	Strongest connection to motor performance on land as measured by the GMFM and the PEDI, AIM was indicated from the water adjustment sub-scale.
Dimitrijevic et al. 2012	Clinical Trial	27 children	14 children in EXPG 13 children in CG	55`, 2 days/wk, 6 weeks	GMFM-88 WOTA2	(p<0,001) in GMFM-88 & WOTA2 at the secondary assessment	GMF skills along with aquatic abilities show improvement in CP children after a 6-week aquatic intervention.
Getz et al. 2007	Clinical Trial	22 children	12 children in EXPG 10 children in CG	30`, 2 days/wk, 32 sessions	PEDI AIM PCC	(p<0,001) in post test on AIM & PEDI in EXPG (p>0,05) in PEDI & PPC between groups	Caregivers refer that aquatic therapy appears improvement on perceived social acceptance and social function.
Retarekar et al. 2009	Single-Subject Report	1 children (5 y.o. girl)	-	50`, 3 days/wk, 12 weeks	COPM GMFM-66	(p<0,001) in GMFM and COPM after the treatment program	Effectiveness on this child with CP was found by this aquatic aerobic exercise program.
Olama et al. 2015	RCT	30 children	15 children in EXPG 15 children in CG	45`, 2 days/wk, 20 sessions in EXPG	Computerized EMG apparatus Electrogoniometer	(p<0,001) in all measure variables comparing pre and post values in favor of EXPG	Significant change on reducing the H-reflex in spastic hemiplegic CP was found by the combination of exercise program and aquatic exercise program.
Hiller et al. 2010	RCT (Pilot)	12 children	6 children in EXPG 6 children in CG	30`, 6 sessions, 6-8 weeks in EXPG	M-ABC PSPCSA	(p<0,001) in posttest for EXPG in M-ABC and PSPCSA	Feasible intervention for children with DCD and may be effective in improving their GMF skills.

5.2. *Hippotherapy*

Hippotherapy is a physiotherapeutic approach widely known in the rehabilitation of children with CP. Even if its use has only begun in the last decade it was the technique with the most available studies. What was observed was that except for two studies only positive results were reported for hippotherapy. All of the studies have a diversity of outcome measures such as GMFM scales (66, 88). EMG, $_{s}$EMG, SAS and the VMC were noted in only six studies. The following scales were observed in only five studies. These are the PBS, BPM, DLS, OLS, RFD, PEDI –FSS, five – point scale, formetic instrument system and the $_{v}$GRF. The discussion of this review is based on the above scales.

Improved muscle symmetry in children with CP, especially symmetry in adductor muscles during walking and other functional motor skills can improve during treatment with hippotherapy (Benda et al. 2003, McGibbon et al. 2009). This view is observed in two RCT's with the same outcome measures (EMG, sEMG and GMFM-88) and the use of groups which lead to valid results. Also, according to the GMFM (66, 88), PEDI-FSS, DLS, OLS, $_{v}$GRF and the RFD , hippotherapy indicated positive changes in trunk balance and strength and is a useful approach to maximize functional performance and reduce the degree of motor disability in children with CP (Drnach et al. 2010, Giagazoglou et al. 2012, Park et al. 2014 and Streba et al. 2002). The above statement is verified in two other studies with VCM measures by the same author. In a 2009 clinical trial there was no existence of control groups and the results showed that hippotherapy

improved trunk and head stability. However, in 2010 control groups were used and the results stated that hippotherapy might improve outcome measures (Shurtleff et al. 2009, Shurtleff et al. 2010). The second study was more reliable and valid. Nevertheless, one RCT with the occurrence of groups and the measures made by the GMFM-66 noted that CP children did not obtain clinically significant impact after hippotherapy (Davis et al. 2009).

Furthermore, a trial with no control groups that used GMFM showed that hippotherapy is recommendable since it maximally mobilizes the reserve possibilities of children (Winchester et al. 2002). Another trial with control groups showed that developmentally delayed children may improve GMF (Lonatamishvili et al. 2004). Another option is for hippotherapy to be used in conjunction with therapeutic exercise for the improvement of back geometry in CP (El-Meniawy & Thabet 2012). However, despite of the positive results of hippotherapy another study shows that hippotherapy is less effective in improving GMFM in Level V on the GMFCS (Hamill et al. 2007). However, this was a case report with limited generalizability. When hippotherapy is not an accessible option, a hippotherapy simulator is a useful alternative for balance (Lee et al. 2014). Finally, the hippotherapy simulator improves posture and balance in Level V in GMFM (Herrero et al. 2012).

Limitations & Further Studies

The under mentioned table 2, present the information of every article that has been analyzed and the restrictions presented below. First limitation in most of the studies was the small sample size, followed by the sample of convenience and time duration of the treatments. Two further restrictions were the lack of

control groups and the diversity of subjects while there were five studies that did not mention limitations. This results in lower reliability and lack of evidence of validity. Thus, it is essential to carry out new investigations that exclude the above limitations.

Table 2

Study	Study Design	Sample	Sample Groups	Treatment Time	Outcome Measures	Results	Conclusion
Lee et al. 2014	RCT	26 children	13 children Hippotherapy Group 13 children Hippotherapy Simulator Group	1h, 3 days/wk, 12 weeks	PBS BPM	Sig. improvements in Hippotherapy Group & Hippotherapy Simulator Group (p>0,05) between groups	Hippotherapy Simulator is a useful alternative to hippotherapy for static & dynamic balance.
Benda et al. 2003	RCT	15 children	7 children Experimental Group 8 children in Control Group	8` in EXP.G. 8` in C.G.	EMG	(p<0,001) in EXP.G. contrary to CG in symmetry of muscle activity.	Improved symmetry in muscle activity in CP after an 8` of hippotherapy.
Ionatamishvili et al. 2004	Clinical Trial	100 children	50 children in Hippotherapy Group 50 children in Control Group	90`-120`, 2-3 days/wk,	Five-point scale	(p<0,001) in Hippotherapy Group in involuntary movements, hyperkinesis, spasticity & motor activity.	Hippotherapy is advisable since it maximally mobilizes the reserve possibilities of children for integrating perceptive and behavioral skills.

El-Meniawy & Thabet 2012	RCT	30 children	15 children in Experimental Group 15 children in Control Group	40`, 1 day/wk, 13 weeks	Formetric Instrument System	(p<0,001) post-treatment between groups (p<0,001) pre/post treatment in EXPG & CG	Hippotherapy may be used in conjunction with therapeutic exercise for the improvement of back geometry in CP.
Davis et al. 2009	RCT	99 children	50 children Experimental Group 49 children Control Group	40`, 1 day/wk, 10 weeks	GMFM-66	(p>0,05) in GMFM-66 between the EXPG & CG	Hippotherapy does not have a clinically significant impact in CP.
Herrero et al. 2012	RCT (stratified single-blinded)	38 children	Experimental Group 19 children Control Group 19 children	15', 1 day/wk, 10 weeks	GMFM-66 SAS	SB and effect size sig. improved in EXPG (p>0,05) in GMFM-6 & SAS	Treatment with HS primarily improves posture and balance in Level V in GMFM.
Hamill et al. 2007	Single-subject report	3 children	-	50`, 1 day/wk, 10 weeks	GMFM-88 SAS	(p>0,05) in GMFM-88 & SAS in the subject	Hippotherapy is less effective in improving GMFM in Level V on the GMFCS
Giagazoglou et al. 2012	Clinical Trial	19 children	10 children in Experimental Group 9 children in Control Group	30`, 2 days/wk, 10 weeks	DLS OLS vGRF RFD	(p<0,001) in EXPG in vGRF & RFD (p>0,05) in DLS & OLS in both groups	Hippotherapy can be used as an effective intervention for improving balance and strength in CP.
Shurtleff et al. 2009	Clinical Trial	11 children	-	45`, 1 day/wk, 12 weeks	VMC	(p<0,001) with large effect size in head/trunk stability	Hippotherapy improves trunk/head stability.

Drnach et al. 2010	Case Study	1 child (10 y.o. boy)	-	1h, 1 day/wk, 5 weeks	GMFM	(p<0,001) in 2/5 dimensions in GMFM. Positive change in trunk balance and strength	5 weeks of hippotherapy are sufficient to produce positive changes in the GMF in children with CP.
Park et al. 2014	Clinical Trial	34 children	23 children Experimental Group 21 children Control Group	45`, 2 days/wk, 8 weeks	GMFM-66 GMFM-88 PEDI-FSS	(p<0,001) in GMFM-66 and GMFM-88 in both groups (p<0,001) in dimension E and GMFM-66 and in PEDI-FSS in EXPG	Maximize functional performance and amelioration of GMF was found my hippotherapy.
Shurtleff et al. 2010	Pilot Study	12 children	6 children Cerebral Palsy Group 6 children Non-Disabled Group	45`, 1 day/wk, 12 weeks	Video Motion Capture	(p<0,001) in movement variability (p<0,001) in trunk/head control as a result of gaining motor learning	Possible improvement in head and trunk stability in CP children by hippotherapy.
Winchester et al. 2002	Clinical Trial	7 children	-	1h, 1 day/wk, 7 weeks	GMFM	(p<0,001) in GMFM (p<0,001) between pre-test and post-test 1 & 2 (p>0,05) between post-test 1 & 2	Developmentally delayed children may improve the GMF by hippotherapy.
McGibbon et al. 2009	RCT	47 children	25 children Hippotherapy Group 22 children Barrel Group	10` both groups (phase 1), 30`, 1 day/wk, 12 weeks (phase 2)	sEMG GMFM-66	Phase 1: (p>0, 05) in BG in AMS, (p<0,001) in HG in AMS Phase 2: (p<0,001) in GMFM-88	Some functional motor skills and adductor muscle symmetry during walking can have a progress with hippotherapy.

Streba et al. 2002	Clinical Trial	17 children	-	1h, 1 day/wk, 18 weeks	GMFM-88	(p<0,001) in GMFM total score (Dimension A-E) after 18 weeks	Reduced degree of motor disability in CP children after hippotherapy was due to improvement of GMF.

5.3. Virtual Reality

VR is the newest research approach of the four discussed for the treatment of CP. Even if studies are limited, especially those examining trunk and posture, VR seems like an enjoyable, safe, motivating and challenging technique (Weiss et al. 2014). The following studies show that opinions vary. The results of the studies were reported using different outcome measures which will base the discussion of this report. Some of the outcome measures are GMFM-88, GMFM, TCMS, COPM, MACS, PBS, BOTMP and the posture scale analyzer. Postural scale analyzer and functional mobility was used in a case report in which there were improvements for all parameters studied such as postural control (Deutsch et al. 2012). Moreover, the motion of pelvis and trunk was measured by Vicon 612 optoelectronic system in another case study and indicated increase in coupling of the pelvis to the trunk, as a primary compensation mechanism utilizing the better controlled trunk to conduct rotation of the pelvis (Barton et al. 2013).

However, VR is also a technique that can include games that are more affordable like Nintendo Wii or Kinect. Especially, Nintendo Wii was found to be a potential rehabilitation tool for the management of function disorders in children with CP since the GMFM-88 showed higher scores in all sections after the treatment (Gordon et al. 2012). But this was a pilot study (n=6) with low

generalizability. In a clinical trial, the ROM of spine and hip joints were evaluated after the implementation of serious games and noted differences between the groups were seen. This study consisted of only of two children (1= CP, 1= healthy) (Barton et al. 2006). This result was confirmed by Bonnechere et al. (2015), who found significant differences in TCMS after treatment in the group of children with CP and suggest the integration of serious games in conventional therapy.

Furthermore, VR based therapy presented possible improvement in balance due to statistically significant differences found in PBS and MACS in both groups of the study (control and experimental) (Deepak et al. 2012). VE-based spatial training is efficient for children with a group of disabilities, specifically when combined with training that positively amends the cognitive weakness (Akhutina et al. 2003). That outcome came up after the second part of this trial which observed improvement in the treatment group in contrast to the first part that showed no differences occurring between groups. Training of sense of agency may help enhance the results of training programmes in children with CP. This was noted in the experimental group when physiological habits in connection to their physical activity level and computer habits were evaluated (Ritterband-Rosenbaumn et al. 2012). Other than these positive effects, VR also provides positive results in social engagement between non-disabled and disabled groups but no effects in motor function and there were no significant differences in COPM between groups (Reid & Campbell 2006). This outcome with different measures (BOTMP, GMFM, muscle strength with Cybex) was found in an RCT with only higher measurements in Cybex and the suggested 12-week hVCT protocol

increases knee muscle strength than motor functions in CP children (Chen et al. 2012). Lastly, a growth in sway velocity was the only significant variation that underpinned by the force plate. The combination of anodal transcranial direct current stimulation combined with mobility training can increase the body sway velocity in children with CP but no relation in postural balance was noted (Lazzari et al. 2015).

Limitations & Further Studies

After the different opinions that are presented for this treatment it is reasonable to analyze the limitations of these studies. It is worth noting that for the total of eleven articles discussed, eight of them did not mention limitations, something that decrease the validity and reliability of the research and the results reported. The other three studies main limitation was the small sample sizes. The second limitation observed is the study design (pilot's studies). One study noted lack of comparison between groups and small amount of sessions (time duration). In order to alleviate the limitations further studies are needed with the exclusion of the above restrictions. Table 3 shows all of the articles details.

Table 3

Study	Study Design	Sample	Sample Groups	Treatment Time	Outcome Measures	Results	Conclusion
Lazzari et al. 2015	RCT (double-blinded)	12 children	6 children in EXPG 6 children in CG	1 session	Force plate under four conditions (static balance)	An increase in sway velocity was the only significant difference observed.	A single session of anodal transcranial direct current stimulation combined with mobility training elicited to lead to an increase in the body sway velocity of CP children.

Deepak et al. 2012	RCT	16 children	8 children in EXPG 8 children in CG	No time, 3 days/wk, 3 weeks	MACS PBS	(p<0,001) in PBS and MACS in both groups	Possible improvement in CP through VR-based therapy in balance.
Deutsch et al. 2008	Case Report	1 child (13 y.o.)	-	60'-90', 11 training sessions	Posture Scale Analyzer, functional mobility	(p<0,001) for postural scale analyzer and functional mobility	Improvement for all studied parameters in this study.
Barton et al. 2006	Clinical Trial (pilot)	2 children	1 healthy 1 CP	1 session	ROM of spine and hip joint	Differences were found between healthy and control in spine and hip joints (p<0,001)	Motion pattern can be analyzed & improved during SG session.
Barton et al. 2013	Single – subject report	1 child	-	30', 2 days/wk, 6 weeks (13 sessions)	Motion of pelvis & trunk (Vicon 612 optoelectronic system)	(p<0,001) in coupling (from angle-angle plots of trunk & pelvis rotations)	With VR increasing coupling appears to be an initial compensation mechanism using the better controlled trunk to drive rotation of the pelvis.
Bonnechere et al. 2015	Clinical Trial	10 children	-	30', 1 day/wk, 4 weeks	TCMS	(p<0,001) in TCMS for all children after treatment	SG could be an interesting option to integrate in the conventional treatment of CP children.
Reid & Campbell 2006	RCT (pilot)	31 children	19 children in EXPG 12 children in CG	90', 1 day/wk, 8 weeks	COPM	(p>0,05) in COPM in both groups	VR provides results for social engagement between non-disabled and disabled but no effects in motor function.
Akhutina et al. 2003	Clinical Trial	21 children(Part 1) 45 children (Part 2)	-	30`-60`, 6-8 sessions, 1 month (Part 1)	2 computer based tests and 2 non computer tasks (Part 1), Benton	No difference was observed between groups (Part 1)	VE-based spatial training is effective for children with complex disabilities, particularly when combined with

				30`-60`, 6-8 sessions	Judgment of Line Orientation test, arrows subtest of the Nepsy, Roads test (Part 2)	Treatment group improved more than control group (Part 2)	training that remediates cognitive weaknesses.
Chen et al. 2012	RCT	28 children	13 children in hVCTG 15 children in CG	40', 3 days/wk, 12 weeks	GMFM, BOTMP, Muscle strength (Cybex)	(p<0,001) in hVCTG higher Cybex measurements, BOTMP scores did not differ	The proposed 12-week hVCT protocol enhances knee muscle strength rather than motor functions in children with CP.
Ritterband-Rosenbaumn et al. 2012	Clinical Trial	40 children	20 children in EXPG 20 children in CG	30', 7 days/wk, 20 weeks	Normal habits in relation to their physical activity level and computer habits	(p<0,001) in EXPG with a larger increase in the number of correct subjective reporting	That training of sense of agency may help to increase the outcome of training programmes in children with CP.
Gordon et al. 2012	Pilot Study	6 children	-	45', 2 days/wk, 6 weeks	GMFM-88	The mean change in the total GMFM score was 7%. It was noted that the mean post-test scores for all sections were higher.	The Nintendo Wii has the potential for use as a rehabilitation tool in the management of children with CP.

5.4. Adeli Suit – Thera Suit Treatment

The Adeli/Thera Suit treatment is a new physiotherapeutic technique based on re-educating the movement patterns of children with CP. This is confirmed by the following studies with some showing positive results while others oppose that view.

As noted in the following table, all of the outcome measures evaluated in the studies are almost the same. The GMFM (66, 88) scales are observed in all studies while there are two studies with the PBS and PEDI scale and only one with the $EI_{HB.}$ According to a case report it is highlighted that after the planned treatment of 18 weeks there was improvement in GMFM-88 and enhanced postural balance (Ko et al. 2014). The effectiveness of the Thera Suit is also observed in a clinical trial with bigger sample size which confirms the previous study. In that trial every patient underwent a detailed evaluation and case history in order to take part in the trial. After an intensive 3-week daily program the re-examination showed a high percentage of positive effect in all patients and an overall improvement in all 5 categories of GMFM-88 (Kunz et al.).

Contrary to the above studies, another case report showed only a slight progress in PEDI and GMFM (66, 88) melioration in posture after the application of the treatment. The general opinion of this study was the attribution of minimal gains in some areas and decline in areas of functional performance (Bailes et al. 2010). In a more advanced form of the above study with more samples and the establishment of control groups, the results were more unequivocal and concluded that there was no demonstrated difference between the group wearing the suit and the group wearing the control suit (Bailes et al. 2011). Unlike that, there was a 3 group research (MAST group, AST group and NDT group) that after the 4 weeks treatment and at follow-up indicate the efficiency of MAST than the other two therapies in children with CP (Khayatzadeh Mahani et al. 2011).

A combination of different therapies was observed and used in three studies. All of the three studies showed improvement and positive effects in GMFM and PBS

in CP children. More specifically, the combined therapies were the Adeli Suit and the NDT (Kim et al. 2016) and the modified suit treatment along with conventional therapy (Alagesan & Shetty 2010) in one case report the thera suit with intensive therapy, aquatic therapy and hippotherapy was investigated (Datorre 2013). This last study showed that all of the discussed therapies in this literature review can be used together in a rehabilitation program for children with CP and yield positive results.

Limitations & Further Studies

Table 4 presents detailed information of the discussed studies. Limitations observed in the studies used were the small sample size which was the main restriction and lead to decreased variability of results. Another limitation is the time duration of the treatments which seemed in three of studies. The lack of control group was also a limitation in two studies and decreases their validity. A lack of blinding and the high cost of treatment were noted in two studies as significant limitations. Only one study had no limitations. Further studies in this treatment are necessary for creating reliable and valid results with the exclusion of the above limitations.

Table 4

Study	Study Design	Sample	Sample Groups	Treatment Time	Outcome Measures	Results	Conclusion
Alagesan & Shetty 2010	RCT (single-blinded)	30 children	15 C.G 15 EX.G	2h daily, 3 weeks (20` short break)	GMFM-88	Mean dif. In EX.G & C.G→ (p<0,001), Between groups→ Pre-test	Modified Suit Treatment along with conv. therapy is effective in GMF.

						(p>0,5), Post-test (p<0,001)	
Ko et al. 2014	Single subject research report	8 y.o girl	-	50` once a week, 18 weeks	GMFM-88 PBS	(p<0,001) in GMFM and PBS between the baseline and the intervention phase.	Improvement in GMF & postural balance.
Bar-Haim et al. 2006	Clinical Trial	24 Children	12 children AST Group 12 children NDT Group	2h daily, 5 times/wk, 4 weeks (20 sessions)	GMFM-66 EI_{HB}	(p<0,001) in GMFM-66 in AST group after 1 month can be attributed to the improved EI_{HB}	AST optimizes these skills in children with a higher level of gross motor functions.
Kim et al. 2016	RCT (single-blinded)	20 children	8 children NDT/AST Group 9 children NDT Group	NDT/AST →NDT 30`, 2 times/d, 5 times/wk AST 30`, 5 times/wk NDT→30`, 2 times/d, 5 times/wk	GMFM-88 PBS	The GMFM, PBS, and (in both groups) showed stat. significant increase (p < 0.05)	AST/NDT was effective in improving the patients' performance in GMFM and PBS.
Datorre 2013	Case Report	12 y.o. boy	-	4h, 5 days/wk, 3 weeks	GMFM-88	Demonstrated improvements at the end of the 3-weeks in all categories of the GMFM	Thera Suit with ITP, aqua therapy and hippotherapy, improves the GMF
Bailes et al. 2010	Case Report	2 children	-	4h, 5 days/wk, 3 weeks	GMFM-66 GMFM-88 PEDI	Slight progress in function in dimension D of GMFM & PEDI Self-care domain. Symmetry, joint motion and posture showed progress	Minimal gains in some areas and decline in others of functional performance
Bailes et al. 2011	RCT (single-blinded)	20 children	10 children EX.G.	4h, 5 days/wk, 3 weeks	PEDI GMFM-66	(p>0, 05) between groups. (p<0,001) within-	Children wearing Thera Suit did not demonstrate

			10 children C.G.			group for the C.G on the GMFM-66 and for the EXP.G on the GMFM-66 and PEDI different skills	improved motor function compared with those wearing a control suit
Khayatzadeh Mahani et al. 2011	RCT	36 children	MAST 12 children AST 12 children NDT 12 children	2h, 5 days/wk, 4 weeks	GMFM-66	All groups in the GMFM after treatment (p < 0,001) and among groups (p < 0,001). In the follow-up study, the GMFM within groups (p >0, 05), but among groups (p <0,001)	The MAST was more effective than using either the AST or the NDT treatment after treatment and at follow-up
Kunz et al.	Clinical Trial	100 children	-	$4^{1/2}$/6h, 6 days/wk, 3 weeks	GMFM-88	There was overall improvement in all 5 test categories (p<0,001)	The GMFM-88 showed a high percentage of positive effect in 100 patients after treatment

6. Conclusion

CP may be one of the most widely known pathologies in children. Hence, the problems that arise have led to new and more innovative therapies that target improved rehabilitation mainly in problems of functionality. The four techniques that have been analyzed, offer positive results in children with CP. Some of these per categories are the promotion of postural support because of the buoyancy in

aquatic therapy. Moreover, the enhancement of the correct movement pattern in hippotherapy and the recovery of posture in virtual reality. Finally, the Adeli/Thera suit offers right position of the body in children with CP. However, physiotherapists should take into concern that every child with CP has its own clinical picture. Therefore, all of the above techniques might not fit to all children. For example, even if all of the above techniques are safe methods might pose risks depending on the severity of cases and how manageable are. Further studies are needed for the evaluation and the effectiveness of the four physiotherapeutic techniques for trunk and posture control and especially for the Adeli/Thera Suit and Virtual Reality for children with CP.

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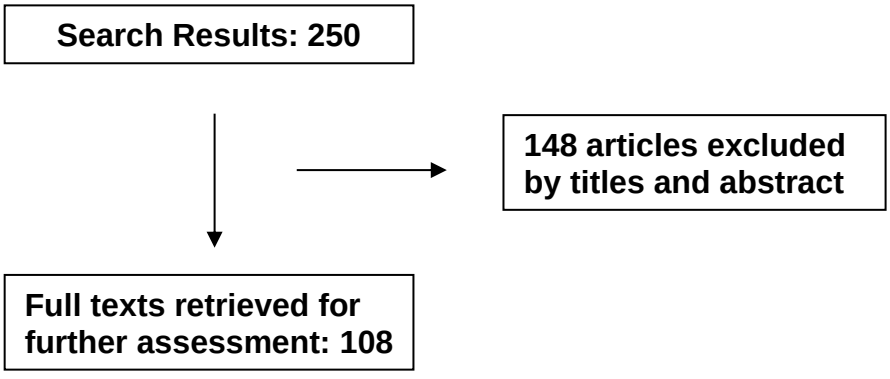
8. Appendices

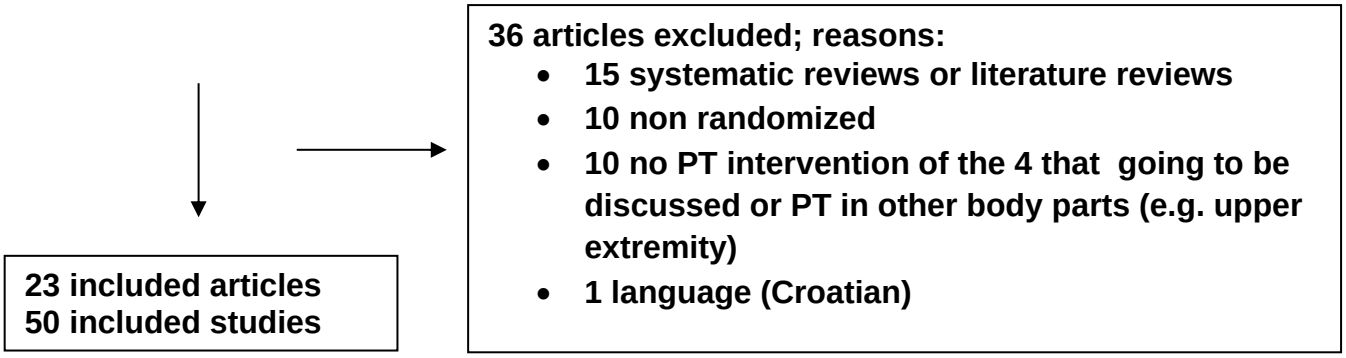
Appendix 1

Musculoskeletal & Movement Disorders	
Abnormal muscles tone (Sanger et al. 2003).	Weakness (Delgado & Albright 2003).
Spasticity (Sanger et al. 2003).	Impaired motor control (Delgado & Albright 2003).
Rigidity (Sanger et al. 2003).	Poor balance (Delgado & Albright 2003).
Hypotonia (Sanger et al. 2003).	Contracture (Delgado & Albright 2003).
Involuntary movements (Sanger et al. 2003).	Skeletal Abnormalities (scoliosis) (Delgado & Albright 2003).
Dystonia (Sanger et al. 2003).	Epilepsy (Delgado & Albright 2003).
Athetosis (Sanger et al. 2003).	Poor trunk & posture stability (Jeon & Shin 2014).

Appendix 2

Article Selection Flow





Appendix 3

Comparison of PEDRO scores in Aquatic Therapy

	Chrysagis et al. 2009	Olama et al. 2015	Hiller et al. 2010	Dimitrijevic et al. 2012
1. Random	Yes	Yes	Yes	Yes
2. Concealed Allocation	Yes	No	Yes	No
3. Baseline Comparability	Yes	Yes	Yes	Yes
4. Blind Subjects	No	No	No	No
5. Blind Therapists	No	No	No	No
6. Blind Assessors	No	No	Yes	No
7. Adequate Follow-up	Yes	Yes	Yes	Yes
8. Intention-to-Treat	No	No	No	No
9. Between Group	Yes	Yes	Yes	Yes
10. Point Estimates & Variability	Yes	Yes	Yes	Yes
Total Score	**6/10**	**5/10**	**7/10**	**5/10**

Appendix 4

Comparison of PEDRO scores in Hippotherapy

	Lee et al. 2014	Benda et al. 2003	El-Meniawy &	Davis et al. 2009	Herrero et al. 2012	McGibbon et al. 2009

			Thabet 2012			
1. Random	Yes	Yes	Yes	Yes	Yes	Yes
2. Concealed Allocation	No	Yes	No	Yes	Yes	Yes
3. Baseline Comparability	Yes	No	Yes	Yes	Yes	Yes
4. Blind Subjects	No	No	No	No	No	No
5. Blind Therapists	No	No	No	No	No	No
6. Blind Assessors	No	No	No	No	Yes	Yes
7. Adequate Follow-up	No	Yes	No	No	Yes	Yes
8. Intention-to-Treat	No	No	No	No	Yes	No
9. Between Group	Yes	Yes	Yes	Yes	Yes	Yes
10. Point Estimates & Variability	Yes	Yes	Yes	Yes	Yes	Yes
Total Score	**4/10**	**5/10**	**4/10**	**5/10**	**8/10**	**7/10**

Appendix 5

Comparison of PEDRO scores in Virtual Reality

	Lazzari et al. 2015	Deepak et al. 2012	Reid & Campbell 2006	Chen et al. 2012
1. Random	Yes	Yes	Yes	Yes
2. Concealed Allocation	No	No	No	No
3. Baseline Comparability	Yes	Yes	No	Yes
4. Blind Subjects	Yes	No	No	No
5. Blind Therapists	Yes	No	No	No
6. Blind Assessors	No	No	Yes	No
7. Adequate Follow-up	Yes	No	No	Yes
8. Intention-to-Treat	No	No	No	No
9. Between Group	Yes	Yes	Yes	Yes

10. Point Estimates & Variability	Yes	Yes	Yes	Yes
Total Score	**7/10**	**4/10**	**4/10**	**5/10**

Appendix 6

Comparison of PEDRO scores in Adeli Suit – Thera Suit

	Alagesan & Shetty 2010	Kim et al. 2015	Bailes et al. 2011	Mahani et al. 2011
1. Random	Yes	Yes	Yes	Yes
2. Concealed Allocation	No	No	No	No
3. Baseline Comparability	No	Yes	Yes	Yes
4. Blind Subjects	No	No	No	No
5. Blind Therapists	No	No	No	No
6. Blind Assessors	Yes	Yes	Yes	Yes
7. Adequate Follow-up	No	Yes	Yes	Yes
8. Intention-to-Treat	No	No	Yes	No
9. Between Group	Yes	Yes	Yes	Yes
10. Point Estimates & Variability	Yes	Yes	Yes	Yes
Total Score	**4/10**	**6/10**	**7/10**	**6/10**