



Prevention and Rehabilitation

# Virtual reality in the rehabilitation process for individuals with cerebral palsy and Down syndrome: A systematic review



Jamile Benite Palma Lopes<sup>a</sup>, Natalia de Almeida Carvalho Duarte<sup>a</sup>,  
Roberta Delasta Lazzari<sup>b</sup>, Claudia Santos Oliveira<sup>a, c, \*</sup>

<sup>a</sup> Health Sciences Program, Faculty of Medical Sciences of Santa Casa de, São Paulo, Brazil

<sup>b</sup> Programs in Rehabilitation Sciences, Movement Analysis Lab, University Nove de Julho, Brazil

<sup>c</sup> University Center of Anápolis, Goiás, Brazil

## ARTICLE INFO

### Article history:

Received 25 May 2017

Received in revised form

7 February 2018

Accepted 12 May 2018

### Keywords:

Virtual reality

Cerebral palsy

Down syndrome

Movement analysis

## ABSTRACT

**Background:** Childhood neurological diseases result in neuromotor impairment, which affects selective motor control, compromising the acquisition of motor skills and functional independence. The positive results achieved with virtual reality are believed to be related to training in an interactive environment that provides a broad range of activities and scenarios with multiple sensory channels, enabling the creation of exercises at an intensity based on individual need. Therefore, a review was conducted to answer the following question: What are the possible effects of virtual reality for the pediatric population, specifically children with cerebral palsy and Down syndrome?

**Objective:** The objective of the present study was to conduct a systematic review of the literature to determine the possible effects of virtual reality therapy in children with cerebral palsy and Down's syndrome.

**Methods:** The PubMed, Bireme, Scielo and PEDro electronic databases were searched in the period from January to March 2016 using the following keywords: Down syndrome and virtual reality, virtual reality and cerebral palsy, virtual reality and neuropsychiatry, and Down's syndrome and virtual reality. Only randomized controlled trials published in English in the previous 10 years (2007–2016) that addressed the specific purpose of this review and achieved a score of at least 4 points on the PEDro methodological quality scale were eligible for inclusion.

**Results:** The initial research led to the retrieval of 214 articles, which were analyzed considering the inclusion criteria. Eighteen articles were submitted to an appraisal of methodological quality using the PEDro scale, only five of which received a score of four or more points and were described in the present review. Three of the studies selected analyzed children with cerebral palsy and two analyzed children with Down syndrome. Despite the different physiopathological characteristics of the two conditions, the authors employed similar therapeutic methods and evaluations. The results of the studies demonstrated that virtual reality training either alone or combined with motor training leads to improvements in sensory-motor functions and can be used as a complement to other successful rehabilitation interventions in the two populations.

**Conclusion:** Based on the results of the studies included in the present systematic review, despite differences in the characteristics of each population, the objectives and methods proposed by the authors were similar and virtual reality demonstrated promising effects for individuals with cerebral palsy and Down syndrome.

© 2020 Elsevier Ltd. All rights reserved.

## 1. Introduction

### 1.1. Virtual reality

Virtual reality is a computer-assisted, immersive, interactive, three-dimensional technology that gives the user an opportunity to

\* Corresponding author. Graciano A. De Souza, 514 Bougainville, CEP: 75075-580, Anápolis, Goiás, Brazil.

E-mail addresses: [claudia.oliveira@unievangelica.edu.br](mailto:claudia.oliveira@unievangelica.edu.br), [csantos.neuro@gmail.com](mailto:csantos.neuro@gmail.com) (C.S. Oliveira).

have multi-sensory experiences in a virtual environment in real time (Weiss et al., 2004; Sveistrup, 2004). Video games with a virtual reality device have been increasingly used in rehabilitation processes, especially in the field of physical therapy. Researchers and clinicians have explored the use of Nintendo Wii™ as a rehabilitation tool for individuals with motor impairment that affects balance and functional mobility (Silva and Kleinahs, 2006).

The use of virtual reality during motor training activities has demonstrated promising results in terms of improving sensory, motor and adaptive information, which assists in the functional performance of activities of daily living (Pavão et al., 2014). The positive results achieved with virtual reality are related to training in an interactive environment that provides a gamut of multi-sensory activities and movements, the intensity of which can be adapted to the specific needs of the patient. Virtual reality training can be used as an auxiliary tool, adding the element of play to conventional therapy to stimulate the active participation of the patient, thereby facilitating the development of perceptions and motor skills (Pavão et al., 2014).

The scientific community has studied therapeutic virtual reality training for use in rehabilitation processes directed at movement disorders in individuals with special needs. However, scientific material on this issue remains scarce (Lin and Wuang, 2012). Virtual reality enables social inclusion and provides both physical and cognitive benefits to individuals with cerebral palsy and Down syndrome by stimulating the practice of activities through experiences with new tasks and sensations, thereby improving quality of life (Bomono and Rosseti, 2010; Mattern-Baxter et al., 2009).

### 1.2. Down Syndrome

Down Syndrome a genetic disease caused by an additional inheritance of chromosome 21 and is the most common chromosome disorder among live births (Aiello-Vaisberg, 1999). In the United States, it is estimated that 5400 of the four million children born per year have Down syndrome, which is a proportion of one out of every 700 births (Lewada et al., 2016). Such individuals have a higher mortality rate in the early years of life in comparison to the general population, which is attributed to internal congenital malformations and a broad range of clinical complications (Bell et al., 1989; Mikkelsen et al., 1990). It is also estimated that at least 100 thousand children in Brazil have a diagnosis of this condition. Children with Down syndrome generally exhibit congenital anomalies, including heart or gastrointestinal defects, varying degrees of intellectual disability, hypotonia and ligament laxity. Hypotonia is correlated with delayed development with regard to fine and gross motor skills as well as speech acquisition and cognitive capacity (Santos et al., 2010).

### 1.3. Cerebral palsy

Cerebral palsy is a term for a group of motor development disorders due to a primary brain lesion, which leads to musculoskeletal problems and limitations regarding activities of daily living (Rosenbaum et al., 2007). The prevalence of cerebral palsy ranges from 1.5 to 2.5 per 1000 live births, with little or no differences among Western nations. Motor impairment is the major manifestation in children with this disease, which leads to abnormalities in the biomechanics of the body (De Kegel et al., 2010; Swanenburg et al., 2008). Moreover, such children may exhibit intellectual, tactile, visual and hearing impairments, which, together with restrictions regarding motor tasks, affect functional performance to a varying extent (Paneth et al., 2006; Kavcic and Vodusek, 2005).

Impaired motor control results in limitations regarding tasks that require precise reach, coordination and dexterity (Dessen and

Pereira-Silva, 2000). As motor development and the follow up of motor skills in schoolchildren constitute important aspects of the learning process (Paneth et al., 2006; Kavcic and Vodusek, 2005), the aim of the present study was to perform a systematic review of the literature to determine the effects of virtual reality training on children with cerebral palsy and Down syndrome.

## 2. Methods

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), which constitute a set of guidelines for reporting systematic reviews that evaluate healthcare interventions (Moher et al., 2009).

### 2.1. Search strategy

Searches were performed of the PubMed (National Library of Medicine), Bireme, Scielo, and PEDro electronic databases in the period from January to March 2016 using the following key words: Down syndrome and virtual reality, virtual reality and cerebral palsy, virtual reality and neuropediatrics, and Down syndrome and virtual reality and neuropediatrics and cerebral palsy. Only randomized controlled studies published in English in the previous 10 years (2007–2016) that addressed the specific purpose of the present review and achieved a score of at least 4 points on the PEDro methodological quality scale were eligible for inclusion.

### 2.2. Eligibility criteria

Only randomized controlled clinical trials that met the following criteria were included in this review: 1) studies involving individuals with Down syndrome or cerebral palsy with no restrictions imposed regarding age, sex or nationality; 2) virtual reality used as the sole intervention or part of the intervention; 3) comparison to a control group involving either no treatment or sham treatment; 4) publication between 2007 and 2016; and 5) score of at least 4 points on the Pedro methodological quality scale.

### 2.3. Review process

All retrieved studies were cross-referenced and duplicate studies were deleted. Relevant titles were highlighted. Abstracts and full texts were reviewed for inclusion by a single reviewer.

### 2.4. Data extraction

The following data were extracted: authors, year of publication, study type, group, intervention, training frequency/duration and outcomes.

### 2.5. Methodological quality

The methodological quality of the studies preselected for the present systematic review was assessed using the PEDro scale (Sherrington et al., 2000), which has demonstrated good levels of validity and reliability (Macedo et al., 2010; Maher et al., 2003). The PEDro scale evaluates the risk of bias and the statistical reporting of randomized clinical trials through 11 items: eight related to methodological quality (e.g., random allocation, allocation concealment, etc.) and two related to statistical reporting (e.g., between-group comparisons, point estimates and variability). As the first item is an eligibility criterion related to external validity, it is not counted as part of the total score. The total PEDro score ranges from zero to 10 points, with a score of 6 points or greater

considered indicative of high quality and a score of less than 6 points considered indicative of low quality. The pre-selected studies needed to have a score of at least 4 points on this scale to be included in the present review.

### 3. Results

#### 3.1. Search results

A total of 214 articles on the effects of virtual reality training for children with cerebral palsy and Down syndrome were retrieved from the databases, 35 of which were pre-selected based on the eligibility criteria. After an analysis of the titles and abstracts, five articles were found not to be available for full-text analysis, 10 were duplicated in different databases and two were excluded following the full-text analysis for not meeting the eligibility criteria. The 18 pre-selected articles were submitted to the analysis of methodological quality by two independent reviewers, 13 of which were excluded from the review for not achieving at least 4 points on the PEDro scale. Thus, five articles were selected for the present systematic review (Fig. 1).

One hundred studies were found in the PubMed (National Library of Medicine) database, 23 of which met the eligibility criteria for pre-selection. Twenty-four studies were found in the PEDro database, 12 of which were preselected, but some were excluded for being duplicates found in other databases. The search of the SciELO database was the least productive, rendering only three articles, all of which were duplicates of articles found in the PubMed database. Ninety-seven articles were found in the Bireme Virtual Library, but only two of which met the eligibility criteria.

#### 3.2. Description of studies

After the review of the methodological quality of the pre-selected studies, five articles were included in the present systematic review. Table 1 displays the PEDro scores for the five articles analyzed.

The data listed in Table 1 demonstrate that all five articles analyzed scored between 6 and 8 points on the methodological quality scale, which is at least two points higher than the minimum defined for inclusion in the present systematic review. “Eligibility”, “key results”, “comparison between groups” and “precision and variability” were marked positive in all studies. “Confidential allocation” and “blinded therapists” were marked negative in all studies. The other quality appraisal categories were marked positive in some studies and negative in others.

Table 2 lists the different types of virtual reality training, comparisons between experimental and control groups and the evaluation methods employed before and after virtual reality motor training in the five studies. Only one study combined this intervention with motor training. Lin HC et al. (2012) analyzed the effects of complementing virtual reality training with treadmill training, whereas the other studies employed virtual reality alone. The frequency of the training sessions was between two and three sessions per week in all studies. The duration, however, varied, with 20-minute to one-hour sessions held for six to 24 weeks.

Despite the different physiopathological characteristics of cerebral palsy and Down syndrome, similar methods were used among the studies regarding the choice of therapy and evaluations. The authors employed virtual reality as a means for motor training. Although the main characteristic of Down syndrome is cognitive

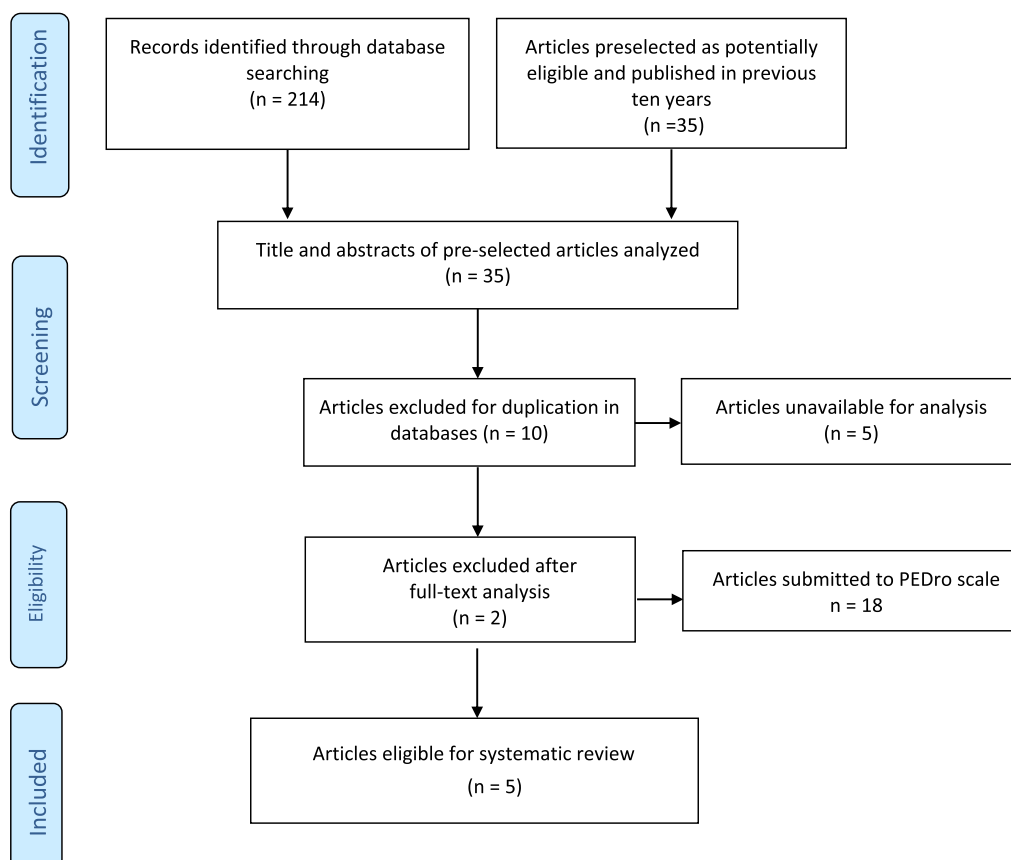


Fig. 1. Flowchart of studies included in literature review.

**Table 1**  
Methodological quality scores (PEDro scale) of articles included in systematic review.

Reference	Item												Score
	Eligibility	1- Randomized allocation	2- Confidential allocation	3- Similar prognosis	4- Blinded subjects	5- Blinded therapists	6- Blinded evaluators	7- Key results	8- Intention to treat analysis	9- Comparison between groups	10- Precision and variability		
Shira Yalon-Chamovitz and Weiss, (2008)	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10	
Yee-Pay Wuang et al. (2011)	Y	N	N	Y	N	N	Y	Y	N	Y	Y	5/10	
Hsiu-Ching Lin and Wuang. (2012)	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10	
Ji-won Shin et al. (2015)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5/10	
C.L. Chen et al. (2013)	Y	Y	N	N	Y	N	N	N	Y	Y	Y	5/10	

Y: yes; N: no.

**Table 2**  
Characteristics of articles included in systematic review.

Authors and year	Study design	Sample	Intervention	Frequency/Duration	Outcomes
Chamovitz and Weiss (2008)	Clinical Trial	EG: n = 15	EG: Gesture Tek GX CG: Routine activity	30 min a day 2 to 3 times a week 12 weeks	1- Short feedback questionnaire 2- Observational scale 3- Self-esteem questionnaire
Wuang et al. (2011)	Clinical Trial	CG: n = 53 EG: n = 52	CG: SOT EG: Virtual reality with Wii™	1 h per day 2 times a week 24 weeks	1- BOT-2 2- VMI 3- TSIF
Lin and Wuang. (2012)	Clinical Trial	EG: n = 46	EG: Virtual reality training + treadmill CG: Short-term physical training	20 min 3 times a week 6 weeks	1- Hand-held dynamometer 3- WISC-III
JW Shin et al. (2015)	Clinical Trial	EG: n = 16 CG: n = 8	EG: Virtual reality training CG: Conventional neurological therapy	45 min per day 2 times a week 8 weeks	1- GMFCS 2- VRG 3- DTVP-2
CL Chen et al. (2013)	Clinical Trial	EG: n = 13	EG: hVCT CG: Physical activity at home	40 min per day 3 times a week 12 weeks	1- Isokinetic dyanamometer 2- GMFM 3- ABMD

CG: control group; EG: experimental group; N: Sample Number; GX: Gesture Xtreme; SOT: standard occupational therapy; hVCT: home-based virtual cycling training; BOT-2: measure of motor proficiency; VMI: visual motor integration test; TSIF: test of sensorial integration function; WISC-III: Wechsler Intelligence Scale for Children; GMFCS: Gross Motor Function Classification System; VRG: virtual reality training group; DTVP-2: Korean Developmental Test of Visual Perception; GMFM: Gross Motor Function Measure; aBMD: areal bone mineral density.

impairment, children with this syndrome exhibit motor limitations in the performance of activities of daily living, especially in tasks involving reaching, precise movements, coordination and postural control. All studies with both populations (cerebral palsy and Down syndrome) found that virtual reality training favored improvements in motor coordination and sensory-motor functions and can be used as a complement to other rehabilitation interventions, such as treadmill training. Thus, similar therapeutic approaches and evaluation criteria were used with the different populations and promising results were found when virtual reality was employed either alone or in combination with motor training.

#### 4. Discussion

Motor development and the follow up of motor skills in school-age children with neurological disorders are of extreme important. In this respect, virtual reality training is a powerful learning tool for use in the rehabilitation process to improve motor problems stemming from abnormal muscle tone (Willrich et al., 2009).

Motor impairment in children with neurological disorders results in limitations regarding the performance of activities of daily living, especially tasks that require reaching, precision, coordination, the parameterization of movements and postural control. Thus, improvements in the performance of motor functions

constitute an important goal in the rehabilitation process (Dessen and Pereira-Silva, 2000). The articles included in the present systematic review demonstrate that virtual reality training offers promising results through sensory-motor activation, which can assist in the functional performance of activities of daily living. Three of the studies involved individuals with cerebral palsy (Chamovitz and Weiss, 2008; Chen et al., 2013; Shin et al., 2015) and two involved individuals with Down syndrome (Willrich et al., 2009; Weiss et al., 2014). Therefore, a review was conducted to answer the following question: What are the possible effects of virtual reality for the pediatric population, specifically children with cerebral palsy and Down syndrome?

In a study not included in the present review, PL Weiss et al. (2014) stress the fundamental role of virtual reality training for individuals with cerebral palsy, concluding that the use of this form of intervention is promising due to the fact that it has become more accessible and increasingly popular among clinicians who work with rehabilitation. Based on the technological advances of virtual reality, including the development of simulation techniques, one may opt for the creation of new virtual environments or adapt the existing technology to the needs of clinical practice. This enables the use of virtual reality for the rehabilitation of different motor disorders, as this technique is adequate for the development of the cognitive, motor and emotional aspects of patients within the

context of specific therapeutic goals (Lin and Wuang, 2012). The searches conducted in the present study for the identification of relevant articles revealed the importance and numerous possibilities of virtual reality as an intervention protocol for individuals with neurological diseases (Darekar et al., 2015; Doná et al., 2015).

In a study involving eight individuals with cerebral palsy allocated to an experimental group submitted to eight weeks of virtual reality training and a control group submitted to eight weeks of neurological physical therapy, Shin et al. (2015) concluded that a well-designed training program involving virtual reality can help improve coordination in this population (Dessen and Pereira-Silva, 2000). In a study involving a quite innovative method (Nintendo Wii™ games) in a sample of 105 patients allocated to an experimental group submitted to virtual reality training and a control group submitted to conventional therapy. YP Wuang et al. (2011) concluded that virtual reality training with Nintendo Wii™ games leads to improvements in sensory-motor functions in children with Down syndrome and can be used as a complement to other successful rehabilitation interventions. However exist a huge need to study virtual reality in neurological individuals, being knowing that in different aspects, games or variables can be noticed in promising results associated with this method in a study of a systematic review with analytical method, we can realize that virtual reality intervention showed a strong effect in improving motor function in children with CP when comparing with conventional therapy or controls, therapy that help children with improve their motor skills. By decreasing these barriers or enhancing the enablers, a child with CP may gradually decrease impairments of his/her body structure and function and activity limitations, and gradually improve participation in school, communities, and society (Chen et al., 2013).

Among the clinical trials included in the present review, only one combined virtual reality training with treadmill training (Kavcic and Vodusek, 2005). The others either employed virtual reality alone or compared the method to conventional physical therapy (Chamovitz and Weiss 2008; Wuang et al., 2011); Lin & arm function, ambulation, and postural control in children with CP and sensorial with children Down Syndrome With regard to clinical implications, VR can motivate children to participate in the intervention (Chen et al., 2013; Lewada et al., 2016).

Human studies have shown that improving arm function requires hundreds of repetitions per day of a challenging functional task to lead to structural neurological change (Chen et al., 2013).

## 5. Conclusion

Based on the findings of the studies included in the present systematic review, despite differences in the characteristics of each population, the objectives and methods proposed by the authors were similar and virtual reality demonstrated promising effects for individuals with cerebral palsy and Down syndrome through sensory-motor activation, assisting in functional activities. Thus, when well-designed, virtual reality training in the rehabilitation process can lead to improvements in cognitive, motor and social aspects.

## Acknowledgments

The authors declare no conflicts of interest.

Grant support: The authors gratefully acknowledge financial support from the Brazilian fostering agencies Fundação de Amparo à Pesquisa (FAPESP - 2015/14952- 9 and 2016/11156-0), and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

## References

- Aiello-Vaisberg, T.M.J., 1999. Sonhos de nascimento e preocupação materna primária. *Psychê* 3, 131.
- Bell, J.A., Pearn, J.H., Firman, D., 1989. Childhood deaths in Down's Syndrome. Survival curves and causes of death from a total population study in Queensland, Australia, 1976 to 1985. *J. Med. Genet.* 26, 764–768.
- Bomono, L.M.M., Rosseti, C.B., 2010. Aspects in perceptual-motor development and sensory-motor intelligence in Down syndrome. *Rev. Bras. Crescimentodesenvolv. Hum.* 3.
- Chamovitz, Y.S., Weiss, P.L., 2008. Virtual reality as a leisure activity for young adults with physical and intellectual disabilities. *Sci. Dir.* 29, 273–287.
- Chen, C.L., Chen, C.Y., Liaw, Y.M., et al., 2013. Efficacy of home-based virtual cycling training on bone mineral density in ambulatory children with cerebral palsy. *Osteoporos. Int.* 24, 1399–1406.
- Darekar, A., McFadyen, B.J., Lamontagne, A., et al., 2015. Efficacy of virtual reality-based intervention on balance and mobility disorders post-stroke: a scoping review. *J. NeuroEng. Rehabil.* 12–46.
- De Kegel, A., Dhooge, I., Peersman, W., Rijckaert, J., Baetens, T., Cambier, D., et al., 2010. Construct validity of the assessment of balance in children who are developing typically and in children with hearing impairments. *Phys. Ther.* 90, 1783–1794.
- Dessen, M.A., Pereira-Silva, N.L., 2000. Deficiência mental e família: uma análise da produção científica. *Cad. Psicol. Educ. Paid.* 10, 12–23.
- Doná, F., Aquino, C.C., Gazzola, J.M., 2015. Changes in postural control in patients with Parkinson's disease. *Aposturographic study. J. Pysiol* 102 (3), 272–279.
- Kavcic, A., Vodusek, B.D., 2005. A historical perspective on cerebral palsy as a concept and a diagnosis. *Eur. J. Neurol.* 8, 582–587.
- Lewada, A.F., Matsonff, A., Revenis, M., et al., 2016. Preoperative evaluation and comprehensive risk assessment for children with Down syndrome. *Pediatr. Anesth.* 26, 356–362.
- Lin, H.C., Wuang, Y.P., 2012. Strength and agility training in adolescents with Down syndrome: a randomized controlled trial. *Res. Dev. Disabil.* 33, 2236–2244.
- Macedo, L.G., Elkins, M.R., Maher, C.G., Moseley, A.M., Herbert, R.D., Sherrington, C., 2010. There was evidence of convergent and construct validity of physiotherapy evidence database quality scale for physiotherapy trials. *J. Clin. Epidemiol.* 63 (8), 920–925.
- Maher, C.G., Sherrington, C., Herbert, R.D., Moseley, A.M., Elkins, M., 2003. Reliability of the PEDro scale for rating quality of randomized controlled trials. *Phys. Ther.* 83 (8), 713–721.
- Mattern-Baxter, K., Bellamy, S., Mansoor, J.K., 2009. Effects of intensive locomotor treadmill training on young children with cerebral palsy. *Pediatr. Phys. Ther.* 21, 308–319.
- Mikkelsen, M., Poulsen, H., Nielsen, K., 1990. Incidence, survival and mortality in Down syndrome in Denmark. *Am. J. Med. Genet.* 7, 75–78.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann. Intern. Med.* 151 (4), 264–269.
- Paneth, N., Hong, T., Korzeniewski, S., 2006. The descriptive epidemiology of cerebral palsy. *Clin. Perinatol.* 33, 2251–2267.
- Pavão, S.L., Arnoni, J.L.B., Oliveira, A.K.C., et al., 2014. Impacto de Intervenção em realidade virtual sobre o desempenho motor de uma criança com paralisia cerebral: estudo de caso. *Rev. paulista de Pediatr.* 32, 389–394.
- Rosenbaum, P., Paneth, N., Leviton, A., Goldstein, M., Bax, M., 2007. A report: the definition and classification of cerebral palsy. *Dev. Med. Child Neurol.* 49 (109), 8–14.
- Santos, A.P.M., Weiss, L.I., Almeida, G.M.F., 2010. Assessment and intervention in the motor development of a child with Down syndrome. *Rev. Bras. Ed. Esp. Marília* 16, 19–30.
- Sherrington, C., Herbert, R.D., Maher, C.G., Moseley, A.M., 2000. PEDro. A Database of Randomized Trials and Systematic Reviews in Physiotherapy.
- Shin, Jw, Song, G.B., Hwangbo, G., 2015. Effects of conventional neurological treatment and a virtual reality training program on eye-hand coordination in children with cerebral pals. *J. Phys. Ther. Sci.* 27, 2151–2154.
- Silva, M.F.M.C., Kleinahas, A.C.S., 2006. Cognitive processes and brain plasticity in Down syndrome. *Rev. Bras. Edc. Esp* 12.
- Sveistrup, H., 2004. Motor rehabilitation using virtual reality: review. *J. NeuroEng. Rehabil.* 1, 10–18.
- Swanenburg, J., De Bruin, E.D., Favero, K., Uebelhart, D., Mulder, T., 2008. The reliability of postural balance measures in single and dual tasking in elderly fallers and non-fallers. *BMC Musculoskel. Disord.* 162.
- Weiss, P., Rand, D., Katz, N., Kizony, R., 2004. Video capture virtual reality as a flexible and effective rehabilitation tool. *J. NeuroEng. Rehabil.* 1, 12.
- Weiss, P.L., Tirosh, E., Fehlings, D., 2014. Role of virtual reality for cerebral palsy management. *J. Child Neurol.* 29, 119–1124.
- Willrich, A., Azevedo, C.C.F., Fernandes, J.O., 2009. Desenvolvimento motor na infância: influência dos fatores de riscos e programas de intervenção. *Rev. Neurocienc.* 17, 51–56.
- Wuang, Y.P., Chiang, S.C., Su, Y.C., et al., 2011. Effectiveness of virtual reality using Wii gaming technology in children with Down syndrome. *Sci. Dir.* 32, 312–321.