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Posturography in the analysis of postural control in children with cerebral palsy: a literature review

Posturografia na análise do equilíbrio

em crianças com paralisia cerebral: revisão de literatura

Posturografía en el análisis del equilibrio en niños con parálisis cerebral: revisión de literatura

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ABSTRACT | Children with cerebral palsy (CP) have reduced postural control given that sensory and motor functions are compromised. There are several functional protocols for balance analysis, but few studies have used the force platform as an instrument of precision in this assessment. The objective of this review was to identify published articles that employed this evaluation of children with CP and to analyze the used protocols and parameters. To this effect, a search was carried out through the BVS in the following databases: LILACS, IBECs, MEDLINE, Cochrane Library, SciELO. A total of 165 articles were found, from which 16 were selected on the basis of the inclusion and exclusion criteria. Studies have shown that the parameters of medial-lateral and anterior-posterior linear displacement of the center of pressure and the sway ratio have been used more frequently, and that the evaluation time of the force platform, in most studies, does not exceed 20 seconds. This review demonstrates that children with typical development present better postural control, and children with CP can increase their balance via specific interventions, including the use of force platform.

Keywords | cerebral palsy; postural balance; evaluation.

RESUMO | Crianças com paralisia cerebral (PC) apresentam menor equilíbrio postural pelo comprometimento de funções motoras, sensoriais e centrais. Existem diversos protocolos funcionais para análise do equilíbrio, mas poucos estudos têm utilizado a plataforma de força como instrumento de precisão nessa avaliação. O objetivo desta revisão foi identificar artigos publicados que utilizaram essa avaliação em crianças com PC e analisar os protocolos e parâmetros utilizados. Para tanto, foi realizada uma busca nas seguintes bases de dados: LILACS, IBECs, MEDLINE, Biblioteca Cochrane e SciELO, por meio da Biblioteca Virtual em Saúde. Foram encontrados 165 artigos; a partir dos critérios de inclusão e exclusão, foram selecionados 16 artigos. Os estudos mostraram

que os parâmetros lineares de deslocamento médio-lateral e anteroposterior do centro de pressão e a razão desses deslocamentos têm sido utilizados com maior frequência, e que o tempo de avaliação na plataforma de força, na maioria dos estudos, não excede os 20 segundos. Foi demonstrado ainda que crianças com desenvolvimento típico apresentam melhor controle postural, e que crianças com PC podem incrementar seu equilíbrio a partir de intervenções específicas, inclusive em plataforma de força.

Descritores | paralisia cerebral; equilíbrio postural; avaliação.

RESUMEN | Niños con parálisis cerebral (PC) presentan menor equilibrio postural por el compromiso de sus funciones motoras, sensoriales y centrales. Existen diversos protocolos funcionales para el análisis del equilibrio, pero pocos estudios utilizan la plataforma de fuerza como instrumento de precisión en esta evaluación. El objetivo de esta revisión fue identificar artículos publicados que utilizaran esta evaluación en niños con PC y analizar los protocolos y parámetros utilizados. Por lo tanto, fue realizada una búsqueda en las siguientes bases de datos: LILACS, IBECs, MEDLINE, Biblioteca Cochrane y SciELO, por medio de la Biblioteca Virtual en Salud. Fueron encontrados 165 artículos y a partir de los criterios de inclusión y exclusión, fueron seleccionados 16 artículos. Los estudios han demostrado que los parámetros lineales de desplazamiento medio-lateral y antero-posterior del centro de presión y la proporción de estos desplazamientos, han sido utilizados con mayor frecuencia y que el tiempo de evaluación en la plataforma de fuerza, en la mayoría de los estudios, no excede los 20 segundos. Fue demostrado también que niños con desarrollo típico presentan mejor control postural, y que niños con PC pueden incrementar su equilibrio a partir de intervenciones específicas, inclusive en plataforma de fuerza.

Palabras clave | parálisis cerebral; equilibrio postural; evaluación.

This study was conducted at the Physical Education School of *Universidade de Brasília* (UnB) - Brasília (DF), Brazil.

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INTRODUCTION

The term cerebral palsy (CP) refers to a group of postural and movement disorders resulting from a nonprogressive and permanent brain lesion that occurs during the development of the immature brain, causing limitations in the daily life of the subject¹⁻³. Studies point spasticity, joint deformities and muscle imbalance as the main causes for changes in the musculoskeletal system, which are able to interfere with the postural control of children with CP, as well as sensory changes observed in these children, such as visual, auditory and vestibular deficit^{1,2,4,5}.

Therefore, it becomes important to assess the balance in these subjects. There are many evaluation protocols, from precise instruments to observational evaluations, with qualitative and quantitative methods. However, the most precise way to assess postural control is posturography, measuring body oscillation during the semi static erect posture by means of force platforms⁶.

However, few studies have used this instrument in children with CP⁷. Thus, the objective of this study was to identify published articles that used the posturography to assess postural control in children with CP and analyze the used protocols and parameters.

METHODOLOGY AND RESULTS

A systematic search of publications on postural balance in children with CP was conducted. The search included the databases LILACS, IBECs, MEDLINE, Cochrane library and SciELO. The following keywords were used: cerebral palsy AND postural control OR balance. In the initial search, by means of resources from the databases, studies performed with children aged less than two years old or with adults which have not been published in Portuguese or English and those published prior to 2002 (Stage I) were excluded. After this initial search, the assessment based on the title, abstract and keywords was performed, and the following inclusion criterion was added: the use of a force platform as an instrument to assess balance, and, as exclusion criteria, the studies of post-surgery evaluation and literature review (Stage II). The analysis of full texts (Stage III) was performed with the objective to find assessments of postural balance in children and adolescents with minimum conditions to be analyzed in the force platform, standing up or sitting down.

In Stage I, 165 articles were found. The evaluation of title, abstract and keywords reduced the sample to 47 studies. In Stage III, the full texts were analyzed, and at the end there were 16 articles that met the criteria (Table 1).

DISCUSSION

The studies presented samples of subjects that ranged from 7 to 23 people, with mean of 12 subjects (± 5.7), and mean age of 5 to 11 years old. Two articles that assessed postural balance in the sitting position and 14 that analyzed the standing position were found.

Even though we found only two studies analyzing children in the sitting position^{8,9}, we recognize the importance to better understand body balance in this position. Due to balance changes and the global motor compromise, most subjects with CP remain sitting for a long time, and this is how they participate in the daily life activities. This situation happens because they cannot remain standing and, even if they can, they perform better when sitting down, or even because they spend too much energy by standing up. Liao et al.⁹ emphasize as a priority in the rehabilitation of these subjects that they can get maximum function in the sitting position.

Both studies used groups with spastic CP in the sample, comparing them with children with typical development (TD), but with different methods to assess balance (Table 2).

Cherng et al.⁸ assessed balance sitting down with the feet of the subjects against the force platform. The authors concluded that postural stability in the sitting down position goes through changes according to the seat inclination and in a comparable way between children with CP and TD. The anterior inclined seat provided better postural balance and functionality in the reaching task for both groups. However, with the posterior inclined seat, the displacement of the medial-lateral center of pressure (COP) was greater in the group with CP.

Liao et al.⁹ used the platform as a supporting base for sitting down. It was observed that COP displacement in the medial-lateral and anterior posterior directions is greater in the group with CP, but there was statistical difference only in the lateral displacement of the dynamic balance. Such results suggest that children with CP acquired trunk stability and mechanisms of static balance similar to those of children with TD,

Table 1. Description of studies that used the force platform to assess the postural balance in children with cerebral palsy

Study	Publication (IF)	Participants	Type of study	Tasks	Position
Nobre et al. ⁷	Eletromyogr Clin Neurophysiol (NF)	10 CP (7.9±2.07 years) 9 TD (7.5±1.58 years)	Comparative	Bipodal support OE and CE	Standing
Cherng et al. ⁸	Rev Dev Disabil (4.04)	10 CP (7.8±1.48 years) 16 TD (8.8±1.89 years)	Comparative	Balance and reach	Sitting
Liao et al. ⁹	Am J Phys Med Rehabil (1.58)	20 CP (3 to 8 years) 20 TD (3 to 8 years)	Comparative	Bipodal support stable base Recovering balance: Oscillatory base	Sitting
Shumway-Cook et al. ¹⁰	Dev Med Child Neurol (2.92)	6 CP (9.1±2 years)	Quasi-experimental	Balancing and recovering balance: anterior and posterior disturbance	Standing
Woollacott et al. ¹¹	Dev Med Child Neurol (2.92)	6 CP (9.3 years)	Quasi-experimental	Bipodal support Balancing and recovering balance: anterior and posterior disturbance	Standing
Burtner et al. ¹²	Dev Neurorehabil (1.58)	8 CP (5.37±2.06 years) 36 TD (2 to 10 years)	Comparative	Bipodal support Recovering balance: posterior disturbance	Standing
Chen e Woollacott ¹³	J Mot Behav (3.10)	7 CP (11.1±1.7 years) 8 TD (8.64±3.32 years)	Comparative	Bipodal support Recovering balance: posterior disturbance	Standing
Ferdjallah et al. ¹⁴	Clin Biomech (2.07)	11 CP (9.9±3.5 years) 8 TD (2.7±2.7 years)	Comparative	Bipodal support OE and CE	Standing
Rose et al. ¹⁵	Dev Med Child Neurol (2.92)	23 CP (11.2±4.7 years) 92 TD (10.9±3.7 years)	Comparative	Bipodal support OE and CE	Standing
Correa et al. ¹⁶	Eletromyogr Clin Neurophysiol (NI)	10 CP (7.3±1.8 years) 10 TD (7.6±2.1 years)	Comparative	Bipodal support Stable base Control group: Unstable base (foam)	Standing
Druzbecki et al. ¹⁷	Acta Bioenge Biomech (0.45)	18 CP (6 to 14 years)	Experimental	Bipodal support OE and CE	Standing
Liao e Hwang ¹⁸	Percept Mot Skills (0.49)	15 CP (8.5±1.91 years)	Correlational	Bipodal support Balancing and recovering balance: Visual feedback. OE and CE, oscillatory visual information, OE with oscillatory base, CE with oscillatory base, oscillatory visual information with oscillatory base, lateral rhythm, unipodal support and tandem support	Standing
Donker et al. ¹⁹	Exp Brain Res (2.39)	10 CP (7 years) 9 TD (8 years)	Comparative	Bipodal support OE, CE and visual feedback	Standing
Ledebt et al. ²⁰	Motor Control (1.53)	10 CP (5 a 11 years)	Quasi-experimental	Bipodal support Balance with visual feedback Static (keeping the focus on the target) Dynamic (moving focus to the target in circle. lateral or randomized)	Standing
Rha, Kim e Park ²¹	Yonsei Med J (0.22)	21 CP (6.1±1.09 years) 22 TD (5.64±0.49 years)	Comparative	Bipodal support Without and with orthosis	Standing
Reilly et al. ²²	Arch Phys Med Rehabil (2.282)	8 CP (4 to 14 years) 11 TD (4 to 14 years)	Comparative	Bipodal support Open base and closed base + Attention and memory cognitive tests	Standing

IF: impact factor; CP: cerebral palsy; TD: typical development; OE: open eyes; CE: closed eyes; NI: not informed

and demonstrated that the tasks concerning static balance may not be sufficient to detect the difficulties of balance in this population.

The other studies assessed the balance in children with CP in the standing position (Table 3). The mobile platform was used to for the analyses and intervention in a study (divided into two publications)^{10,11}, and only as an evaluation instrument in other two studies^{12,13}.

The therapeutic use of the mobile platform seems to cause positive effects with practice, because the results showed that the postural control in children with CP can be changed after intense training (5 days with 50 anterior disturbances and 50 posterior disturbances/day), also suggesting that children with spastic diplegia CP need more prolonged training than hemiplegic patients due to the different forms of motor or sensory and motor compromise found between these two groups¹⁰.

Table 2. Procedures of studies that assessed postural balance in the sitting position

Study	Attempts	Time of evaluation (seconds)	Position of hands	Position of feet	Assessment parameters
Cherng et al. ⁸	3	7	Under the thighs	Feet supported against the force platform	1. AP and ML displacement of COP 2. <i>Sway ratio</i> 3. Ground reaction force
Liao et al. ⁹	1	10	Along the body	Supported feet and knees at 90°	1. AP and ML displacement of COP 2. <i>Sway index</i> 3. <i>Sway ratio</i>

AP: anterior posterior; ML: medial-lateral; COP: center of pressure

Table 3. Procedures of studies that assessed postural balance in the orthostatic position

Study	Attempts	Time of evaluation (Seconds)	Position of hands	Positio of feet	Assessment parameters
Woollacott et al. ⁵	5 for each condition	NA	NI	One foot per platform	EMG
Nobre et al. ⁷	1	30	Along the body	Self-selected	AP and ML displacement
Shumway-Cook et al. ¹⁰	5 for each condition	10	NI	One foot per platform	1. AP and ML displacement 2. Time of stabilization
Burtner et al. ¹²	NI	NA	NI	Shoulder width	AP and ML displacement
Chen e Woollacott ¹³	NA	NA	Arms crossed over the chest	Self-selected	1. Rotation 2. Difference between COP and COG [§]
Ferdjallah et al. ¹⁴	2	20	Along the body	Self-selected	1. AP and ML displacement 2. NRMS
Rose et al. ¹⁵	5 for children with CP or aged until 6 years old; 10 for the others	30	Along the body	Self-selected	1. Displacement speed 2. Mean radial displacement 3. Mean frequency
Côrrea et al. ¹⁶	1	60	NI	Shoulder width	AP and ML displacement 1. Length of COP displacement 2. Ellipsis area 3. Vertical and horizontal displacement of COG
Druzbecki et al. ¹⁷	NI	NI	NI	NI	1. AP and ML displacement 2. AP/ML ratio
Liao e Hwang ¹⁸	3	7 to 10	NI	NI	1. AP and ML displacement 2. AP/ML ratio
Donker et al. ¹⁹	1	60	Along the body	Pelvic width Shoe and use of orthosis	1. Mean displacement amplitude 2. Normalized displacement 3. Entropy
Ledebt et al. ²⁰	NI	NI	Along the body	Pelvic width Shoe and use of orthosis	1. AP and ML displacement 2. Time of COP on the target
Rha, Kim e Park ²¹	3	20	Along the body	One foot per platform	1. AP and ML displacement 2. Ground reaction force
Reilly et al. ²²	NA	NA	NI	Open base (one foot per platform) Closed base (feet together)	1. Displacement speed 2. RMS

AP: anterior posterior; ML: medial-lateral; NRMS: Normalized root mean square; EMG: electromiography; COP: center of pressure; COG: center of gravity; NI: not informed; CP: cerebral palsy; RMS: root mean square; NA: Non-applicable.

Burtner et al.¹² and Chen and Woollacott¹³ used the mobile force platform only to analyze balance and verified lower postural control in children with CP in comparison to children of the same age and level of motor development, but without CP. Therefore, the hypotheses of the authors that the balance variables can be considered in the differentiation between children with or without CP were corroborated.

From the other analyzed studies, five of them used the force platform aiming to compare the balance variables between groups of children with CP and with TD^{7,14-17}. These articles also point to the lower postural control in groups with CP.

Nobre found lower COP mean oscillation in the anterior posterior direction among children with CP in the conditions of eyes open and closed. His results suggest that children with TD use more ankle strategies to promote balance, causing more oscillation than children with no ability to use this strategy, besides mentioning that the group with CP was under constant intervention with focus on the balance training⁷.

The position of the body, arms and the support base, as well as the time in the force platform and the number of assessment attempts can influence the balance evaluation, be it for biomechanical reasons or for the subject's fatigue — that is why it is important to establish standardization criteria for these elements. In the analyzed studies, we observed there are different protocols of evaluation (Table 3).

In relation to the position of the support base, most studies use the feet distance self-selected by the research subjects^{7,13-15}. As to the position of the arms, we also observed convergence between most protocols, which follow the evaluation with relaxed arms along the body^{7,14,15,18-22}. Such preference for a more comfortable feet and arm position can be explained by the specific characteristics of the children population, with changes in movement and comprehension, thus facilitating the application of the protocol.

The time of evaluation in the force platform does not exceed 20 seconds in 50% of the studies^{9,11,14,21}. In the others, the analyses are conducted with the limit of 60 seconds^{16,19}, and at least 7 seconds¹⁸. In the articles, we did not find the theoretical base for the performance of short evaluations, but we believe that the reduced time to measure balance enables the participation of these subjects who, due to the characteristics of CP, demonstrate lower tolerance to long balance assessments.

Likewise, we believe that the specificities of CP, together with the aspects of childhood, in the sense

that it is more difficult to apply extensive and detailed methods and protocols, justify the reduced number of task attempts. Despite the differences between protocols, we observed there are usually two to five attempts in most studies^{8,14,15,18,21}, but some make only one attempt^{7,9,16,19}.

The balance parameters that are most used in the studies are the maximum medial-lateral and anterior posterior COP displacements. Other measures are also used, such as the displacement ratio (sway ratio), and speed of COP and RMS (root mean square) displacement.

Only one study with experimental design was found, with the randomization of groups and the assessment of balance in a force platform using the blind-condition strategy during evaluation¹⁷. The authors found that the experimental group of children with CP using a specific ankle-foot orthosis and practicing physical therapy exercises presented improvement in relation to the control group, which only practiced exercises. However, as shown in Table 3, this study did not report several aspects of the evaluation protocol, like time of evaluation, number of attempts, position of arms and legs at the time of evaluation, which makes it difficult to replicate the study and better understand it.

CONCLUSION

According to the research, there are still few studies that use the force platform to understand the behavior of balance in children with CP, especially the assessment of balance in the sitting position. Most articles perform comparative studies between children with CP and TD. Only one study with experimental design was found, which used the force platform to assess a specific intervention.

The sample size seems to be a limiting factor of the studies due to the reduced number of participants in the found articles.

The difficulties of movement and postural control of CP seem to be relevant aspects in the creation of assessment protocols for these children in the force platform, becoming less strict as to the position of the body, the number of attempts and the time of evaluation.

The analyzed articles showed that the linear parameters of medial-lateral and anterior posterior displacement in the COP and the ratio of these displacements have been more frequently used as parameters to assess balance from the force platform.

The evaluations of balance in the force platform demonstrated differences between the groups of children with TD and children with CP, and they were able to detect the improvements caused by interventions in the force platform or specific therapeutic practices.

Therefore, we believe that new studies using this assessment instrument and with larger samples can collaborate with the better understanding of aspects concerning postural balance of children with CP, leading to more efficient interventions and treatments.

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