Cerebral palsy: Influence of TheraTogs® on gait, posture and in functional performance

Paralisia cerebral: Influência do TheraTogs® na marcha, postura e no desempenho funcional

Raquel Ehlert, Eliane Fátima Manfio, Regina de Oliveira Heidrich, Rafael Goldani*

Universidade Feevale, Novo Hamburgo, RS, Brazil

Abstract

Introduction: For children with cerebral palsy, orthoses take an important role in improving posture, gait, functional performance and preventing secondary musculoskeletal disorders. Objective: To evaluate the influence of TheraTogs® on the posture, distribution of plantar pressure during gait and functional performance of a child with spastic diplegia cerebral palsy. Methods: A quantitative evaluation was carried out on a case study in which an 11-year-old child diagnosed with diplegic cerebral palsy underwent postural assessment through the Postural Assessment Software (PAS), plantar pressure distribution assessment during barefoot gait through the Emed-X system, before and after the intervention period of 8 weeks and functional assessment (Pediatric Evaluation of Disability Inventory - PEDI), with and without TheraTogs®. Results: In posture, TheraTogs® had greater influence on hip extension and this change was greater during its use. In the plantar pressure distribution assessment, an increase in posteriorization of plantar pressure occurred in the initial contact, the performance of the push-off phase and initial swing phase improved. In functionality, the child showed improvements in mobility, however, their self-care ability with TheraTogs® was reduced. Conclusion: Although improvements in posture, gait and functionality were verified with the
Introduction

In 2006, the Executive Committee of the International Workshop formulated a definition that describes cerebral palsy (CP) as a group of permanent disorders of the development of posture and movement, attributed to non-progressive disturbances in fetal or child development. The motor disorders caused by cerebral palsy, generally, are associated with language, cognitive, sensory, perceptual and behavioral changes, in addition to epilepsy and secondary musculoskeletal problems (1). The muscle shortening and deformities (secondary musculoskeletal problems) in CP children are due to biomechanical misalignment during motor development stages and daily-life activities and cause pain, loss of mobility and compromise the locomotor system, increasing susceptibility to surgical interventions (1 - 6).

In this sense, orthoses play an important role in the treatment of CP children and are recommended for the support of a body segment or for inhibiting involuntary movements. The objective of the orthoses is to increase the function, prevent deformities and contractures, keep the extremities at a functional position, aid in the function of weak muscles and facilitate the selective motor control (7). However, orthoses can be fixed, made of rigid materials, operating in positioning the segment and muscle length passively, or they can be dynamic and besides positioning the segment they may allow for active user participation in the movement, providing mobility and improvement in the muscle function during gait (8, 9), for instance.

The use of flexible dynamic orthotic garments, such as TheraTogs®, has been suggested to improve the ability to stabilize the posture, to correct or prevent deformities, improve functionality and to enable the user a more appropriate functional pattern (10 - 17). However, studies have shown that aspects such as the lack of practicality, difficulties in the toilet tasks, discomfort and the heat caused by this type of orthosis, hinder adhesion and adaptation to use (11 - 15).

TheraTogs®, the object of this study, is a dynamic orthotic garment, which, according to the
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made with the forefoot and maintained predominantly throughout the stance phase. The subject presents equinovalgus feet (more pronounced on the right), collapse of the plantar arch and valgus hallux, predominantly on the right; difficulties in locomotion in environments with uneven ground, requiring the support of another person; and slow gait speed.

This study was approved by University Frevale-RS ethics committee on human research (02610112.7.0000.5348). Informed consent was signed by the child’s guardian, as per Resolution 196/96.

This study used the Full Body TheraTogs® system (orthoses) (Figure 1), consisting of vest and shorts with straps (outer straps customized system) to facilitate trunk extension, reduce shoulder protraction, stimulate lower abdomen proprioception, facilitate external rotation and hip extension.

In this study, after a period of gradual adaptation to the orthosis (one week- two or more hours, depending on tolerance), the child wore the orthosis for eight weeks, from 8 to 10 hours a day, during daily-life activities. The child’s guardian (mother) was trained and received a DVD recording, with a step-by-step demonstration on the fitting of TheraTogs® in the child. Markings were made in TheraTogs® to facilitate and improve fitting. All necessary support was offered, with weekly monitoring in person to control the fitting of the orthesis, as well as for possible questions or clarifications.

The Postural Assessment Software (PAS) was used for postural assessment, with and without TheraTogs® before and after the intervention period to establish and document the main changes related to the static posture of the child. The marked points followed the PAS protocol (20) and the C = child was assessed on the left and right side (Figure 1C). The following angles were used in the analysis: Trunk inclination: angle between the greater trochanter and the acromion and the vertical line; Hip angle: angle between the anterior superior iliac spine, greater trochanter of the femur and joint line of the knee; Knee angle: angle between the greater trochanter of the femur, joint line of the knee and lateral malleolus; and Ankle angle: angle between the joint line of the knee, lateral malleolus and head of the second metatarsal bone.

Data on the plantar pressure distribution was obtained during barefoot gait, by using a pressure platform (Emed X-Novel, GbmH) with capacitive...
sensors at a resolution of 4 sensor/cm², and at an acquisition rate of 100 Hz. Plantar pressure data during barefoot gait, were processed by using the Software Novel (21). The plantar pressure distribution outcomes measured in this study, according NOVEL (21) were: peak plantar pressure (PPP); total contact time (TCT) and total contact area (TCA).

During the collection of data on the plantar pressure, the child walked barefoot at self-selected speed, for a distance of approximately 5 meters. Five repetitions were considered valid (feet inside the floor area of Emed-X platform). After the adjustment period with the orthosis, four plantar pressure assessments were carried out during gait: pre-test1 - without the orthosis (PRE1) and pre-teste2 - with the orthosis (PRE2), carried out before the intervention period; post-test1 - without the orthosis (POST1) and post-test2 - with the orthosis (POST2), performed after the intervention period.

The Pediatric Evaluation for Disability Inventory (PEDI) (22) was applied for assessing functionality with and without the orthosis. PEDI uses the scaled scores of the three scales for functional skills (Part I) and the three scales for caregiver assistance (Part II) as assessment baselines. In addition, after the intervention period, an interview with the child’s guardian was applied, which addressed five issues regarding the perception of responsibility in relation to comfort, practicality and acceptance of the orthosis by the child. During the intervention period a diary was used to record the time of use of the orthosis.

Figure 1 - Child’s posture without TheraTogs® and with TheraTogs®, in front view (A), back view (B) and left side view (C)
Data analysis

Means and standard deviations were presented for data on the postural assessment and plantar pressures. The means between the situations (PRE1 and PRE2, POST1 and POST2) were compared in percentage terms.

PEDI data were analyzed according to the scaled scores of the three scales for functional skills (Part I) and the three scales for caregiver assistance (Part II) (22).

Results

Data on the postural assessment of the child (Table 1) on the right side and left planes are presented in degrees and compared in percentages for assessments with and without TheraTogs® before the intervention period (PRE1, PRE2) and after the intervention period (POST1-POST2; PRE1-POST1; PRE2-POST2).

Figure 2 shows the plantar pressure distribution during the gait of the child, with and without TheraTogs®, in the assessments before and after the intervention period. We found that he use TheraTogs® contributed to the posteriorization of plantar support, especially after the intervention period (POST2), in which contact in the midfoot region (POST1 and POST2) and hindfoot region (heel) (POST2) increased. In addition, with TheraTogs® both before (PRE2) and after the intervention period (POST2), there was no contact of the right hallux in the swing phase when using the pressure platform as noted in PRE1 (Figure 2A). Furthermore, after the intervention period we did not observe contact of the hallux, after the intervention period, without TheraTogs® (POST1).

Table 2 presents data on plantar pressure outcomes (pressure peaks Planting Contact Total Area and Total Dwell Time) during gait with and without TheraTogs® in evaluations before and after the intervention period. Plantar pressure peaks for the feet (left and right) were presented relating to the regions of the hindfoot (heel), midfoot, forefoot (metatarsals) and hallux (Table 2). The use of TheraTogs® for 8 weeks (POST1 and POST2) caused increased plantar pressure peaks in the midfoot and hindfoot regions, thus showing a posteriorization of the plantar support. We also highlight immediate changes (PRE2) caused by TheraTogs®, with increased pressure peaks in the midfoot region (Table 2).

### Table 1 - Data for postural assessment (in degrees and percentages)

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Joint Angle</th>
<th>PRE1</th>
<th>PRE2</th>
<th>POST1</th>
<th>POST2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LS</td>
<td>RS</td>
<td>LS</td>
<td>RS</td>
<td>LS</td>
</tr>
<tr>
<td>Trunk extension (°)</td>
<td>159</td>
<td>166</td>
<td>178</td>
<td>177</td>
<td>167</td>
</tr>
<tr>
<td>Hip extension (°)</td>
<td>104</td>
<td>117</td>
<td>141</td>
<td>147</td>
<td>118</td>
</tr>
<tr>
<td>Knee extension (°)</td>
<td>148</td>
<td>145</td>
<td>160</td>
<td>154</td>
<td>143</td>
</tr>
<tr>
<td>Ankle angle (°)</td>
<td>88</td>
<td>86</td>
<td>89</td>
<td>84</td>
<td>85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Joint Angle</th>
<th>PRE1-PRE2</th>
<th>POST1-POST2</th>
<th>PRE1-POST1</th>
<th>PRE2-POST2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LS</td>
<td>LS</td>
<td>LS</td>
<td>RS</td>
<td>LS</td>
</tr>
<tr>
<td>Trunk extension (%)</td>
<td>12</td>
<td>7</td>
<td>2</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Hip extension (%)</td>
<td>36</td>
<td>26</td>
<td>9</td>
<td>-2</td>
<td>13</td>
</tr>
<tr>
<td>Knee extension (%)</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>2</td>
<td>-3</td>
</tr>
<tr>
<td>Ankle angle (%)</td>
<td>1</td>
<td>-2</td>
<td>0</td>
<td>-3</td>
<td>-3</td>
</tr>
</tbody>
</table>

Note: PRE1(before intervention period-without TheraTogs®); PRE2 (before intervention period-with TheraTogs®); POST1 (after intervention period-without TheraTogs®) e POST2 (after intervention period-with TheraTogs®). LS-Left Side; RS-Right Side. +values = increase in extension/angle; -values = decrease in extension/angle.
As to the total contact area (ACT), before the intervention period (PRE1), a difference of approximately 10% between the left foot and the right foot (Table 2) was observed, such difference is related to the asymmetries observed in the postural assessment (Table 1). After the 8-week intervention period (POST1), the TheraTogs® caused the transference of the body weight to the right side, increasing TCA and decreasing asymmetry between the right and left feet (±5%). We also found that after 8 weeks of use of TheraTogs® (POST2) changes continue to be seen as to the plantar pressure distribution during gait, increasing the TCA for the left foot (Table 2).

In addition, we found that the use of TheraTogs® (PRE2 and POST2) caused an average increase of 18% in the total contact time (TCT) after the intervention period. In the evaluations without TheraTogs® (PRE1 and POST1) we did not observe changes in the TCT during gait.

Regarding the functionality (PEDI) in the area of mobility, in the functional skills domain, the child showed an improvement of 8% in the scaled score.
In the caregiver assistance domain, the functionality score increased by 13%, with less aid needed when the child wore TheraTogs® (Table 3). In the self-care domain, as to the functional skills, no changes were detected. However, in the caregiver assistance domain, the child’s scaled score of 30% decreased, and more help was required for the tasks. There were no differences in the child’s score in both areas related to the social function with and without the orthosis (Table 3).

Along with functional assessment results, the child’s mother reported that the lack of practicality for fitting and removing the TheraTogs® due to the large number of velcro straps attached to the orthosis turned the child more dependable in activities such as changing clothes and accessing the toilet, making the child more likely to urinate and evacuate on their own clothes. Furthermore, the mother reported that the orthosis caused a lot of heat during its use.

Table 2 - Data on the plantar pressure distribution during gait

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Plantar Pressure Outcomes (average ± standard deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foot</td>
</tr>
<tr>
<td>Contact Area (cm²)</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>74.2 ± 5.6</td>
</tr>
<tr>
<td>Right</td>
<td>66.7 ± 3.3</td>
</tr>
<tr>
<td>Total Contact Time (ms)</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>676.7 ± 45.1</td>
</tr>
<tr>
<td>Right</td>
<td>713.3 ± 25.2</td>
</tr>
</tbody>
</table>

Pressure Peaks (kPa) – Regions of the foot (average values)

| Foot             | Left  | wp | wp | 17 ± 6 | 47 ± 6 |
|                 | Right | wp | wp | wp     | wp     |
| Forefoot         |       |    | 56 ± 8 | 74 ± 12 | 64 ± 11 | 79 ± 10 |
| Midfoot          |       |    | 90 ± 39 | 142 ± 18 | 134 ± 43 | 118 ± 40 |
| Hindfoot         |       |    | 257 ± 37 | 235 ± 25 | 262 ± 50 | 233 ± 45 |
| Hallux           |       |    | 287 ± 16 | 291 ± 46 | 307 ± 73 | 329 ± 70 |

Note: PRE1 (before intervention period-without TheraTogs®); PRE2 (before intervention period-with TheraTogs®); POST1 (after intervention period-without TheraTogs®); POST2 (after intervention period-with TheraTogs®). wp = without pressure peaks.

Table 3 - Comparative data on the composed scores of PEDI questionnaire, in the assessments before (PRE1) and after the intervention period (POST2)

<table>
<thead>
<tr>
<th>Domain</th>
<th>Area</th>
<th>Raw Score</th>
<th>Scaled Score</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional Skills</td>
<td>Self-care</td>
<td>73</td>
<td>59.24</td>
<td>2.40</td>
</tr>
<tr>
<td></td>
<td>Mobility</td>
<td>51</td>
<td>59.24</td>
<td>2.40</td>
</tr>
<tr>
<td></td>
<td>Social Function</td>
<td>63</td>
<td>63.94</td>
<td>2.66</td>
</tr>
<tr>
<td>Caregiver Assistance</td>
<td>Self-care</td>
<td>45</td>
<td>45</td>
<td>69.98</td>
</tr>
<tr>
<td></td>
<td>Mobility</td>
<td>32</td>
<td>81.30</td>
<td>6.57</td>
</tr>
<tr>
<td></td>
<td>Social Function</td>
<td>34</td>
<td>92.32</td>
<td>13.86</td>
</tr>
</tbody>
</table>

Note: -------- = score higher than the minimum scaled score 100 from the reference table for the item, depicting a superior performance in the assessed area (22).
Discussion

In the postural assessment of the child we observed that the use of TheraTogs® caused an increase in the hip extension that reflected in the trunk and knee extension, which is consistent with what was found by Abd El-Kafy (16). The changes were more pronounced in the evaluation before the intervention period (PRE1 and PRE2) than after the intervention period (POST1 and POST2), thus characterizing immediate changes with the use of TheraTogs® (PRE2). The magnitude of the postural changes was lower after the 8-week intervention period with TheraTogs®. This fact may be related postural adaptations caused by the wear of the orthosis and/or a decrease in tension/resistance of the straps due to its use.

No significant changes were observed in the child’s knees and with the use of the orthosis (PRE and POST), given that the orthosis does not act directly in these joints. Furthermore, the changes that occurred in the knee are due to repositioning of the hip. In addition, the fact that the influence of the orthosis was higher on the left side of the body may be related to the child’s clinical data. In this sense, in the standing position and during gait the child presents internal rotation of the lower limbs, more pronounced hip and knee flexion on the right and rotation on her own axis to the left, transferring most of the body weight to the lower left limb. In POST2, in which the changes were greater in the right hip, we noticed that the child transferred the body weight to the lower right limb, unlike observed at baseline (PRE1).

Abd El-Kafy (16) studied the clinical impact of ground reaction orthoses and TheraTogs® in gait parameters of children with spastic diplegia cerebral palsy. For this purpose, a sample of 56 children was divided in three groups: GROUP A- this group underwent neurodevelopmental therapy, including gait training and orthostatism without orthopedic intervention; GROUP B- this group performed the same therapy as GROUP A and wore TheraTogs®; GROUP C- this group underwent the same procedures as GROUP B, associated with the use of ground reaction orthoses. The results of the study showed that the use of TheraTogs® and the ground reaction orthoses increased plantar flexion, knee and hip extension during the stance phase. In addition, speed, pace, and stride length were also increased. As for the GROUP B, significant changes appeared only in increased hip extension and stride length. GROUP A had an increase in hip and knee extension and an increase in speed, pace and length of the stride along the treatment. However, these changes were not statistically significant.

A pattern of back plantar support was observed in the analysis of the plantar pressure distribution behavior during the gait before the intervention period (PRE1 without TheraTogs®), in which the initial contact during the gait, for both feet, was performed with the forefoot. This is a change commonly found in the gait of children with cerebral palsy spastic diplegia (23, 24).

The use of TheraTogs® caused changes in gait, with a posteriorization of the plantar support, increasing the contact of the heel and reducing the contact area of the hallux on the swing phase and especially in the swing phase, in which, in conditions in which there are no neuromusculoskeletal changes, the foot has no contact with the ground (3, 25).

Similar to what was evidenced by Nsenga Leunkeu et al. (26) as to the plantar pressure distribution in children with spastic diplegia PC, in this study we found that the highest plantar pressure peaks occur in the hallux region and in the head of the metatarsals, showing a medial/central pattern, i.e., shifting the load to the medial head of the metatarsals (metatarsal I and metatarsal II), to the left foot and to the right foot. The results relating to the pressure peaks in this study can be associated with the postural assessment data and to observations during the clinical assessment, in which we observed anterior movement of the body in relation to the vertical axis and internal rotation of the lower limbs.

We observed that the position of pelvic antever sion, associated with the semiflexion of hip and knee, the medial knee projection (valgus), valgus ankle and flat feet, in clinical and postural assessment and commonly described in the literature on PC children (4, 23, 27 - 29), have contributed to a shift in the gravity center. This change directly reflected in the plantar pressure distribution on the support base, the feet, causing the anterior plantar support and the medial/central plantar pressure distribution pattern observed in PRE1. The postural asymmetries that were detected collaborate to the lack of uniformity in the plantar pressure distribution pattern between the feet, left and right. In PRE2, the posture imposed by TheraTogs® caused a posteriorization of the plantar pressure, yet, the behavior is still different from
causing a more posterior pelvic displacement during the stance and swing stages.

In this study, the changes imposed by TheraTogs® in the child’s posture and gait were also detected in the functionality, in the mobility area, of the two domains of PEDI questionnaire (functional skills and caregiver assistance), as reported in the literature (12). This gain happened due to an increase in the repertoire of the following functional activities: indoor locomotion: distance/speed, moving from one room to the other without difficulty; locomotion in the external environment: methods, walk without support; when climbing stairs, climb a set of stairs without difficulty and when going down stairs, do it without difficulties.

In contrast, the PEDI showed that the child lost independence in various tasks with the use of TheraTogs®, requiring maximum assistance when wearing the upper and lower body parts, moderate assistance in using the bathroom and minimal assistance in urinary control. On the other hand, without TheraTogs® the child had acquired complete independence in these tasks. Problems such as loss of independence in toilet tasks and difficulties in handling orthopedic garments are commonly reported (12 - 15) and the vulnerability in urinating and evacuating in the orthopedic garments due to lack of practicality (delay in fitting and removing) has also been documented (15). Moreover, the heat caused by the use of TheraTogs® is another disadvantage factor evidenced in this study, in consonance to what has been reported in the literature on this type of orthoses (12 - 15), regardless of being been used in a period with lower temperatures (transition between winter and spring), which can infer major changes when used in hot places or times of the year with higher temperatures.

Conclusions

Finally, the results of this study reveal that with the use of TheraTogs®, some changes in posture were observed, mainly related to the hip extension, plantar pressure distribution, with increased posteriorization of the plantar pressure, of the contact area and total contact time, and of the functionality in the mobility aspect. Despite these changes, the excessive heat, the difficulties in accessing the toilet, in dressing and related to bladder control, were disadvantageous
points in the use of TheraTogs®. We observed that the combination of the use of TheraTogs® with suropodalic-type orthoses or insoles could leverage changes in the plantar pressure distribution, considering the flat feet characteristic, with pronation of the calcaneus, often observed in children with cerebral palsy.

We suggest further research with a higher numbers of subjects and experimental studies to evaluate the influence of the use of TheraTogs® in children with cerebral palsy, in the short, medium and long term. In addition, we suggest studies related to the ideal daily use time of TheraTogs®.

References


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