EFFECTS OF ANKLE-FOOT ORTHOSIS IN CHILDREN WITH CEREBRAL PALSY: A SYSTEMATIC REVIEW OF LITERATURE

Grado en fisioterapia

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Index of abbreviations

CP: cerebral palsy
EC: energy cost
CNS: central nervous system
AFO: ankle-foot orthosis
DAFO: dynamic ankle-foot orthosis
HAFO: hinged ankle-foot orthosis
SAFO: solid ankle-foot orthosis
PLS: posterior leaf-spring orthosis
GMFM: gross motor function measurement
GMFCS: gross motor function classification system
EMG: electromyography
BF: barefoot
ROM: range of movement
1. Abstract:

Study design: systematic review of literature about the effects of ankle-foot orthoses in children with cerebral palsy. Purposes: analyze and gather information on the different articles to conclude on the different effects that can cause the diverse types of devices. Methods: The searches are made in Tripdatabase, Medline and PEDro databases; selected articles were those that accomplished the inclusion and exclusion of the criteria described. A program of critical read was used to guarantee their quality. Results: Stride and cadence are increased using any kind of the braces mentioned. There are also changes in gait kinetic and kinematic parameters, and it is also observed a decrease of oxygen and energy expenditure. Conclusion: Use of ankle-foot orthoses is recommended if the proper guidelines are followed, but there is still a lot of investigation to do in this matter.

Resumen:

Diseño del estudio: Se realiza una revisión sistemática de la literatura en la que se analizan los efectos que causan las ortesis de pie y tobillo en los niños con parálisis cerebral. Propósitos: Analizar y recolectar la información de los diferentes artículos para poder así concluir sobre los efectos que producen los diferentes tipos de ortesis. Métodos: Las búsquedas se realizaron en las bases de datos Medline, PEDro y tripdatabase. Los artículos que se seleccionaron para tener en cuenta en la revisión fueron aquellos que cumplían los criterios de inclusión y exclusión establecidos. Resultados: Se muestra un aumento de la zancada y la cadencia con el uso de los diferentes tipos de ortesis, además de cambios en la cinética y cinemática de la marcha. También se observa un descenso del gasto de oxígeno y energético. Conclusiones: El uso de las ortesis de pie y tobillo es recomendada si se tienen en cuenta las correctas aplicaciones y/o recomendaciones. Aún así, hay mucha investigación que hacer en este campo.
2. Introduction

Cerebral palsy (CP) is mainly designated by central nervous system irregularities, thus loss of selective motor control and abnormal muscle tone, that may changeover in its presentation as an individual grows and develops. [9, 13] As a result of maturation, these principal characteristics usually head to secondary deficits, which include bony deformities, muscle contractures, and gait abnormalities (that are often noted in mobility and balance). Gait abnormalities in children with CP are known to cause a more than two-fold increase in energy cost (EC) of walking compared with wealthy children. [9] Disabilities can be evident in the amount of time and assistance a child needs to complete basic life skills. [13]

CP is a large term and it can be classified in many different ways; the first relating to the part of the body affected: diplegia (both inferior extremities affected and characterized by motor deficits and spasticity typically producing a walking pattern characterized by an equinus ankle position, exaggerated knee flexion and valgus, and increased hip adduction and internal rotation) and hemiplegia (one side of the body affected. They have a characteristic way to walk, hip and knee flexed and the foot in marked equinus on the affected side, or with the hip and knee fully extended and the foot in equinus, producing apparent lengthening and upward tilt of the pelvis on the affected side). [10] Another classification relates to tone abnormalities: spastic (if it’s pure only the pyramidal system is affected. It is characterized by abnormal reflex patterns and increase in muscular tone, and retention of primitive reflexes resulting in abnormal posture and movement patterns [10]), athetoid (extrapiramidal system is involved) and mixed (both systems are injured). [16]

In normal gait, ankle motion is characterized by three rockers. During the first, after initial contact the ankle plantar flexes until the foot is flat on the floor. The ankle begins to dorsiflex, resulting in a rotation of the tibia over the stationary foot (second rocker). The third, or push-off, represents heel-lift at terminal stance. [14] Both the first and the second rocker improve through the use of orthoses [5, 18]. Normal gait is divided in different phases, stance and swing, and each of them subdivided in three phases.

Gait of children with CP, never occur in seclusion. Certainly, they are multiple and consist of primary, secondary and tertiary anomalies. Primary abnormalities are
characterized by the damage to CNS (central nervous system), for example, rectus femoris and hamstring co-spasticity. Secondary anomalies, refer to abnormal bone/muscle growth. Tertiary abnormalities, are those compensations that the individual uses to circumvent the primary and secondary anomalies of gait, and they can be thought of as “coping responses” (abnormal temporal-distance parameters [12]). For example, we take the case explained in primary anomalies, and we know that commonly produces a stiff knee in the swing phase of gait. This leads to problems with foot clearance. Circumduction (coping response) of the swinging limb, by abducting the hip, is a frequent compensation. The “coping responses” will disappear spontaneously when they are no longer required. [10g] Another example of gait anomalies: equinus may be present in swing and stance phase. Anterior tibialis weakness, dysfunction, or premature gastrosoleus contraction causes swing phase drop foot with resultant dragging of the foot, tripping, and proximal joint kinematic compensations. [7]

As we have explained before, the primary brain lesion in CP and secondary alterations in the locomotor apparatus can cause an energy inefficient gait which can often be improved with an orthosis. [18] Ankle-foot orthosis (AFO), is an assistive device that is used to maintain ankle joint stability in the anterior-posterior and medial-lateral directions and also permits and stabilizes motions at the subtalar joint. [15] That is the reason because they are recommended; to prevent or correct dynamic deformity by supporting joint alignment and mechanics. [13]

AFO’s are normally tailor-made and of polypropylene material, which need very high temperatures to mould. They are produced by an orthotic technician, and they have to make them based on a positive modeling, either of plaster or fiberglass, and taking into account the children body segment they want to make the orthosis for. [11]

The principal indications for the use of an AFO in a child with CP who is able to walk are 1) to minimize progressive deformity with growth, 2) to protect an extremity following soft-tissue or skeletal surgery, which typically is performed to address dynamic or myostatic muscle deformities and skeletal transverse plane malalignments, and 3) to improve gait function. [8] There has been proof that the help the wearer in this cases during gait, 1) control the dynamic deformity of equines, establishing a more definitive heel-strike or foot flat posture at initial contact [4]; 2 control dynamic deformity of knee hyperextension during stance; 3) increase knee extension in upright
posture during static standing; and 4) achieve symmetry of motion of the hips and pelvis [7g].

There are different types of AFO’s, dynamic AFO (DAFO®), hinged AFO (HAFO), solid AFO (SAFO) and posterior leaf spring (PLS). The DAFO®s are commonly used for children with neuromuscular affectation, but they can help in other abnormalities. One differential characteristic regarding to other types is the grip of the foot and that they can correct and/or control the frequent postural anomalies (pronation or supination). There are flexible and fit closely.[11] These have been reported as influencing abnormal joint motions through changes in the spastic reflexes and underlying muscle tone by tone –reducing features. Another benefit is to enable maximum midline stability and movement control while permitting freedom of movement. [18] The HAFOs, block the ankle plantarflexion and allow free ankle dorsiflexion during stance for hemiplegic children. [7, 18] It is proved that decrease knee hyperextension by preventing ankle plantarflexion; and that the hinged joint make the HAFO ‘bulky, costly and clumsy’. [14] The SAFO achieves the maximum orthotic control by restricting the movements of both plantar flexion and dorsiflexion in stance and swing phases. Are generally prescribed to reduce excessive plantar flexion in stance, and to prevent or eliminate equine position. [4, 9, 14] The PLS allows plantar flexion as well as dorsiflexion in the stance phase, though both motions are attenuated by a counteracting control moment. Its posterior trim line promotes normal ankle rocker function to create a more dynamic gait. [9] Other goal is to pre-position the foot for heel initial contact, promote puss-off, and achieve foot clearance in swing. [14]
3.Method

This study is a systematic review, made between the months of June and September of 2013, searching the articles published from 1999 to these days, this way we obtain the most recent data collection.

3.1 Strategy and search terms

The database search included MEDLINE, PEDro and Tripdatabase. I contacted the authors of the articles not found by email.

In Medline database, by means of pubmed, the search terms used where “cerebral palsy” AND “orthotic devices”, with a final result of 202 articles. Subsequently I passed a “clinical trial” filter and I obtained a final result of 26 articles. The other search terms I used were “Ankle joint/physiology” AND “orthotic devices”, with a final result of 106 articles. Afterwards, I passed a “clinical trial” filter, and I obtained a final result of 31 articles.

In PEDro, the search terms used were “dynamic ankle-foot orthoses”, with a final result of 55 articles. Afterwards I passed again a “clinical trial” filter in method section, and the final numbers of articles were 4.

In Tripadatabase the search terms where the same as used in PEDro, “dynamic ankle-foot orthoses” with a final result of 26 articles. Subsequently, I passed a “clinical trial” filter, obtaining a final number of 1 article. (Table 1)

Table 1. Strategy and search terms

<table>
<thead>
<tr>
<th>Data bases</th>
<th>Key words</th>
<th>Nº of articles</th>
<th>Filters according to types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medline-Pubmed</td>
<td>-“Cerebral palsy” AND “orthotic devices”</td>
<td>202 articles</td>
<td>-Review: 43</td>
</tr>
<tr>
<td></td>
<td>-“Ankle joint/physiology”</td>
<td>106 articles</td>
<td>-Clinical trial: 26</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Controlled clinical trial: 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Others: 131</td>
</tr>
</tbody>
</table>
3.2 Inclusion criteria

The following inclusion criteria was used to select the articles of our research:

- **Design of the study**: I took into account articles purporting clinical trial as these were the most suitable for consideration.

- **Participants**: Diagnosis of cerebral palsy, aged between months and 20 years.

- **Intervention**: The participants need to be intervened by one of the following AFO design: HAFO, SAFO, PLS or DAFO (appendix 1, 2 and 3).

- **Measurements**: The participants needed to be evaluated through some of the following methods: Gross Motor Function Measure (GMFM 88), Gross Motor Functional Classification System (GMFCS), electromyography (EMG) and gait analysis.

GMFM 88, is a measure designed specifically for children with CP to evaluate change in gross motor function. It is a standardized assessment with demonstrated reliability, validity and responsiveness to changes over time. Descriptions are provided
for different age groups. Distinctions between levels are based on functional limitations, the need for assistive mobility devices and the quality of movement. With 88 items ranging in difficulty from activities in lying and rolling to more complex activities such as hopping, jumping, and stair climbing.

GMFCS, in its use for cerebral palsy, classifies the children in five functional levels depending on the age. On level I, they can walk without restrictions, but they find some limitations in advanced abilities. On level II, they have gait limitations on the outside. On level III, they need assistant devices for walking. On level IV, they work hardly with their hands, and they need constant supervision. And on level V, they usually have a very limited capacity of movement, even though they use an ambulatory aid (appendix 4).

EMG is an electrical recording of muscle activity that aids in the diagnosis of neuromuscular disease.

-Language of the studies: I included the studies drafted in English and Spanish.

-Publication date: To improve the quality of the review the articles selected were finally those published after 1997.

<table>
<thead>
<tr>
<th>Database</th>
<th>Type of study:</th>
<th>Participants:</th>
<th>Intervention:</th>
<th>Publication date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical trial</td>
<td>Children with CP</td>
<td>SAFO, DAFO, HAFO, PLS</td>
<td>1997-2013</td>
<td></td>
</tr>
<tr>
<td>Medline</td>
<td></td>
<td></td>
<td></td>
<td>57 57 31 51</td>
</tr>
<tr>
<td>PEDro</td>
<td></td>
<td></td>
<td></td>
<td>4 4 3 4</td>
</tr>
<tr>
<td>Tripdatabase</td>
<td></td>
<td></td>
<td></td>
<td>4 4 4 4</td>
</tr>
</tbody>
</table>

Table 2. Resum of inclusion criteria

3.3 Exclusion criteria

-I have not taken into account in this research the articles which were not clinical trials, excluding totally systematic reviews.
- I ruled out the articles in which the number of subjects was less than five.

- If the language was not English or Spanish I did not taken them into account.

- If they did not use an AFO device they were excluded.

- If they were adults aged more than 20 with the diagnosis of cerebral palsy were also excluded.

- If the articles were published before 1997 they were rejected.

Finally, after revising the inclusion and exclusion criteria, I reached a total number of 6 articles which were the basis for my study. (Table 3)

### 3.4 Methodological evaluation

To analyze the quality of the articles selected from the literature search, AACPDM was used. It is composed by 5 levels, explained in appendix 5.

Score was fixed as suitable for study inclusion in the review as a level III, the studies below this score were discarded.

<table>
<thead>
<tr>
<th>Article</th>
<th>LEVEL I</th>
<th>LEVEL II</th>
<th>LEVEL III</th>
<th>LEVEL IV</th>
<th>LEVEL V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bjornson 2006</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Russel 2005</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radtka 1997</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buckon 2004</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dong-wook Rha 2009</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Desloovere 2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Table 4. Methodological evaluation by american academy for cerebral palsy and developmental medicine
Electronic search: Data bases: Medline, PEDro, Tripdatabase

390 citations reviewed through the title and abstract

320 do NOT accomplish the established inclusion criteria

Revisions: 49
Sistematic review: 37
Extended primary research: 3
Others: 226

79 items selected from the databases searched

Excluded studies
24 due to the title
2 because age
Repeated 18
4 no AFO types selected for inclusion
7 stroke patients
3 adult participants
6 could not contact the author
6 the authors did not send the article

6 to includ

Non excluded once reviewed full text

TOTAL: 6 included articles
4. Results

4.1 Characteristics of the studies

There were included 6 articles (Bjornson 2006, Russell 2005, Radtka 1997, Buckon 2004, Desloovere 2006, Dong-wook Rha 2009) with a total number of 342 children with cerebral palsy.

Most of the articles included in the study were published in the USA; 1 in Washington, Bjornson 2006; 1 in Portland, Buckon 2004; and the last one, Radtka 1997 in San Francisco, California. With regret to the rest, we have 1 published in Canada, Russel 2005; one in Belgium, Desloovere 2006; and one in Korea, Dong-wook Rha 2009.

Most of the articles studied the use of an AFO design, or if a measurement is sensitive or not.

- 2 studies (Bjornson 2006 and Radtka 1997) assessed the use of DAFO design; one of them, Bjornson 2006, allowed free plantar flexion, and the other, Radtka 1997 stopped free plantar flexion.
- 2 studies (Buckon 2004 and Dong-wook Rha 2009) evaluated the use of HAFO device. Buckon, compares the effect of three braces, one of which is a hinged AFO device; and Dong-wook Rha studied the effect on standing balance control.
- 2 studies (Buckon 2004 and Desloovere 2007) assessed the use of PLS design. Buckon compares the effect of three braces, one of which is a posterior leafspring orthosis; and Desloovere studied how the device affected the push-off.
- 2 studies (Buckon 2004 and Radtka 1997) evaluated the use of SAFO; Buckon compares the effect of three braces, one of which is a SAFO device, and Radtka compares its effects with those caused by the DAFO.
- One article (Russel 2005) determined that the Groos Motion Function Measure is sensitive to changes in function as a result of children who use an ambulatory aid or orthoses in comparison with unaided or barefoot function.
Journal impact factors help us evaluate the importance of a journal. The impact of a journal depends on how often articles in that journal are cited by other academic publications. The more that journal is cited, the greater its impact. The impact factor will help you evaluate a journal's relative importance, especially when you compare it to others in the same field. Due to the relation of the articles dates, as each article is of a different date, we thought convenient to seek the impact factor of the journal in its year of publication:

- Bjorson 2006 which was published in the journal Pediatrics orthopedic had an impact factor in that year of 1.162.
- Russel 2005 which was published in the journal Developmental Medicine & Child Neurology had an impact factor in that year of 1.790.
- Buckon 2004 which was published in the journal Developmental Medicine & Child Neurology had an impact factor in that year of 2.083.
- Dong-wook Rha 2009 which was published in the journal Yonsei Med had an impact factor in that year of 0.772.
- Desloovere 2006 which was published in the journal Gait and Posture had an impact factor in that year of 1.976.
- With Radtka 1997 we had problems due to its date, but what we know for sure is that the journal of the American Physical Therapy Association had an impact factor that was not within 200 journals with higher impact.

With regret to the age of the participants, it also showed some variety. Taking into account the papers that specified this data, the one that had the lower mean was Bjornson 2006, with a mean of 4.3 years, followed by Desloovere 2006 with a mean age of 5.8; Dong-wook Rha 2009 with a mean age of 6.1; Radtka 1997 with a mean age of 6.5; Russel 2005 with a mean age of 7.4; and Buckon 2004 with a mean age of 8.4.

The gender is specified in most of the papers, and the majority of them are male. The studies of Radtka 1997 and Desloovere 2006 do not include this information.

Neither the researches used the same scale to evaluate the function of the children:
Three of them (Bjornson 2006, Russel 2005 and Buckon 2004) used the Gross Motor Function Classification System (GMFCS). Bjornson included children with level I to III, Russel children with level I to IV, and Buckon included children with level I and II.

- Radtaka 1997, used to evaluate the participants the electromyography (EMG).
- Desloovere 2006, used gait analysis, taking into account kinetic and kinematic parameters.
- Dong-wook Rha 2009 did not include any information.

The studies show different types of CP:

- Bjornson 2006, used children with any type of CP.
- Russel 2005, 206 were diagnosed with spastic CP, 13 with dyskinetic CP, 9 with ataxic CP and 27 with hypotonic or mixed CP.
- Radtka 1997 6 had diplegic CP and 4 hemepligic CP.
- Buckon 2004, all the participants were diagnosed with spastic diplegia.
- Dong-wook Rha 2009, all of them where diagnosed with bilateral spastic diplegia.
- Desloovere 2006, all of the patients were diagnosed with hemiplegic CP.

The time for the selection of the sample was not specified in any of the studies.

Duration of the studies and monitoring was different for all the cases. The one that needed more time was Russel 2005; the study was made during a 4 year period. Under 5 years old were evaluated every six months, and annually for children 5 to 16 years old. Bjornson 2006, had an study period of 3 years. Radtka 1997, a 2-year period for the study. Buckon 2004, the participation lasted one year and comprised four visits. The other two (Desloovere 2006 and Dong-wook Rha 2009) do not specified this data.
Table 5. Characteristics of the studies

<table>
<thead>
<tr>
<th>Article</th>
<th>Number of participants</th>
<th>AFO design</th>
<th>Mean age</th>
<th>Gender</th>
<th>Evaluation</th>
<th>Type of CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bjornson 2006</td>
<td>23</td>
<td>DAFO w/ free plantar flexion</td>
<td>4.3</td>
<td>M: 52.2 %</td>
<td>GMFCS (I-III)</td>
<td>Non specified</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F: 47.8 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Russel 2005</td>
<td>257</td>
<td>Non specified</td>
<td>7.4</td>
<td>M: 54.5 %</td>
<td>GMFCS (I-IV)</td>
<td>206 spastic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F: 45.5 %</td>
<td></td>
<td>13 dyskinetic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9 ataxic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>27 hipotonic or mixed</td>
</tr>
<tr>
<td>Radtka 1997</td>
<td>10</td>
<td>DAFO w/ plantar flexion stop / SAFO</td>
<td>6.5</td>
<td>Non specified</td>
<td>EMG</td>
<td>6 diplegic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4 hemiplegic</td>
</tr>
<tr>
<td>Buckon 2004</td>
<td>16</td>
<td>HAFO/PLS/SAFO</td>
<td>8.4</td>
<td>M: 62.5%</td>
<td>GMFCS (I-II)</td>
<td>Spastic diplegia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F: 37.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dong-wook Rha 2009</td>
<td>21</td>
<td>HAFO</td>
<td>6.10</td>
<td>M: 50%</td>
<td>Non specified</td>
<td>Bilateral spastic diplegia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F: 50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desloovere 2006</td>
<td>15</td>
<td>PLS</td>
<td>5.87</td>
<td>Non specified</td>
<td>Gait analysis</td>
<td>Hemiplegia</td>
</tr>
</tbody>
</table>

w/: with M: male F: female
4.2 Synthesis of the results

With the goal of synthesizing and organizing the information as clearly as possible, we decided to organize this section according to different types of AFO devices. Namely, DAFO, HAFO, SAFO and PLS. Finally, we will explain the results that we obtained from Russel 2005, explaining whether the GMFM88 is sensitive to orthotic devices and to ambulatory aids or not.

4.2.1 Dynamic ankle-foot orthoses (DAFO):

The GMFM percentage scores for all dimensions were significantly higher with the patients wearing the DAFO designs (P < 0.001). For independent walkers, level I and II, the change in standing, walking/running/jumping and total GMFM dimension scores was significantly higher (P<0.05), comparing with children using assistive devices (Bjornson 2006).

Measures revealed no differences for the stride length and the cadence depending on the diagnosis, but there were changes at the P<0.05 level for the following interventions: (1) initial 2-week period with no orthoses versus solid AFOs, (2) second 2-week period of no orthoses versus solid AFOs, (3) initial 2-week period with no orthoses versus DAFOs, and (4) second 2-week period with no orthoses versus DAFO's. The mean stride length was increased and the mean cadence was decreased with these devices when compared with no orthoses. (Radtka 1997)

As far as regain joint motions, we know that the amount of ankle plantar flexion that occurred at initial contact and mid-stance in the interventions with no orthoses was reduced with DAFOs. This type of orthosis was recommended for 5 children; in which they observed a benefit in movement of the knee, hip and pelvis. Two of this participants gained velocity and stride length, and three of them stayed the same. They were also recommended for two subjects who showed no differences for joint motions, walking speed and stride length with the DAFO (Radtka 1997).
As data explained for the parents, subjects and their physical therapists this device was lighter, more cosmetically appealing, but slightly more difficult for the children to initially learn to independently don and doff as compared with the SAFO (Rdatka 1997).

4.2.2 Hinged ankle-foot orthosis (HAFO):

One kinetic variable, the peak knee extensor moment in early stance, was signifiﬁcantly increased in the HAFO conﬁguration comparing with the barefoot (BF) condition (P < 0.007). Signiﬁcantly altered ankle kinematics during the stance and swing phases of gait: dorsiflexion at initial contact (p=0.0001), peak dorsiflexion in stance (p<0.009), timing of peak dorsiflexion in stance (p<0.003), peak dorsiflexion in swing (p<0.0002), and dynamic ankle range (p<0.0001) compared with BF. Peak dorsiflexion in stance was signiﬁcantly greater in the HAFO (p<0.001) and the timing of peak dorsiflexion in stance was signiﬁcantly later in the stance phase (P<0.005). They also found changes in the kinetics, (peak dorsiflexion moment in early stance [p=0.0001], peak plantarflexion moment in early stance [p=0.0001], peak power generation in stance [p<0.008], and the timing of peak power generation [p<0.005]) changed signiﬁcantly in this conﬁguration compared again with BF. The absorption did not change, but trend was toward normalization. (Buckon 2004)

Regarding gait parameters, step (P< 0.005) and stride length (P <0.006) were increased compared to BF condition, and the cadence decreased (P<0.005). Therefore, velocity did not increase; it was slower in HAFO, because the cadence decreased 17%, more than in other devices. (Buckon 2004)

Whilst wearing hinged AFOs, correlation (representing ankle control) for ML balance control in children with spastic CP were signiﬁcantly increased (p < 0.05). However, correlation (representing hip load/unload) and (representing transverse body rotation) did not signiﬁcantly change in children with spastic CP whilst wearing hinged AFOs compared to the barefoot condition (p > 0.05). (Dong-wook Rha 2009)

With respect to energy expenditure, energy cost was signiﬁcantly decreased in fast walking (p>0.003), also oxygen consumption (p < 0.001). A few number of
children demonstrated the greatest reduction in energy cost compared with other devices (Buckon 2004).

So as to functional skills, the Bruininks-Oseretsky Test of Motor Proficiency (BOMP) tested that the coordination of the upper-limb and de velocity of this was preferred. (Buckon 2004)

4.2.3 Solid ankle-foot orthosis (SAFO):

Similarly to HAFO, this orthotic design also has kinematic changes in stance and swing phases and kinetic changes. In kinematic, dorsiflexion at initial contact ($p=0.0001$), peak dorsiflexion in stance ($p<0.009$), timing of peak dorsiflexion in stance ($p<0.003$), peak dorsiflexion in swing ($p<0.0002$), and dynamic ankle range ($p<0.0001$) compared with BF. Peak dorsiflexion in stance was significantly worst in the SAFO ($p<0.001$) and the timing of peak dorsiflexion in stance was significantly earlier in the stance phase ($P<0.005$). In kinetics, (peak dorsiflexion moment in early stance [$p=0.0001$], peak plantarflexion moment in early stance [$p=0.0001$], peak power generation in stance [$p<0.008$], and the timing of peak power generation [$p<0.005$]) changed significantly in this configuration compared again with BF. The absorption did not change, but trend was toward normalization. Comparing with PLS devices, the SAFO decreased peak power generation in stance meaningfully ($p=0.003$) (Buckon 2004)

With regret to gait parameters, Buckon 2004 concluded that with this orthosis the timing of the dorsiflexion in stance was less, and Radtka 1997, that at the initial contact the amount of plantar flexion dropped. The length of the stride ($p<0.006$) and step ($p<0.005$) increased compared with BF, while significantly decreasing cadence ($p<0.0005$) (Buckon 2004 and Radtka 1997). The velocity was higher than in HAFO and slower than in PLS, because a drop of a 13% of the cadence, compared once again with BF condition. (Buckon 2004) Radtaka 1997, demonstrated differences at the P<.05 level in stride length and cadence for the following interventions: (1) initial 2-week period with no orthoses versus solid AFOs, (2) second 2-week period of no orthoses versus
solid AFOs, (3) initial 2-week period with no orthoses versus DAFOs, and (4) second 2-week period with no orthoses versus DAFOs.

Concerning energy expenditure, energy cost notably dropped in fast walking (p < 0.003). Oxygen consumption was lower in fast walking, compared with shoes on and BF condition. During the study, the fact that 7 children had higher energy cost reduction with this device was demonstrated. (Buckon 2004)

So as to functional skills, the same as we saw in the HAFO configuration, the Bruininks-Oseretsky Test of Motor Proficiency (BOMP) tested that the coordination of the upper-limb and de velocity of this was preferred. (Buckon 2004)

As we observed in Radtka 1997, these are the clinical recommendations: for 3 participants that gain knee and hip motion, 2 of them also gained gait velocity and stride length.

4.2.4 Posterior leaf spring (PLS):

The same kinetic and kinematic changes we had seen in SAFO and HAFO were tested in this device; the only difference is that the peak of energy generation was lower than in SAFO. The step and stride length also increased this time, and the cadence decreased. With this configuration the drop of velocity was lower than in the other orthoses, because, the cadence only shortened in 11%. Energy cost, velocity and oxygen consumption also decreased, but the last was not significant because a small increase of velocity (they walk faster with this configuration than with HAFO). 7 children demonstrated the energy cost reduction with this device. As we have seen before, the coordination of the upper-limb was better, and the velocity faster. (Buckon 2004)

A) Results comparing with shoes and BF: Walking with the devices improved first and second ankle rocker, as the same time that gained foot security during swing phase (p < 0.01). The stride length and the velocity also increased when compared to BF (P < 0.01). Although plantar flexion moment at push-off increased (p < 0.01), on the other hand, ankle range of motion (ROM), energy generation in pre-swing and ankle velocity at toe-off deteriorated (p < 0.01). Comparing with shoes, either maximum dorsaflexion moment in stance and energy generation in pre-swing did not changed.
However, ankle moment at loading response reached significance \( (p < 0.01) \). Ankle range of motion during push-off was still worse in orthoses compared to shoe walking \( (P < 0.01) \). At knee level children also seemed to benefit significantly from wearing orthoses compared to barefoot. Both orthoses improved knee shock absorption and maximal knee flexion in stance \( (P < 0.01) \), and tended to change maximal knee flexion and timing of peak flexion in swing \( (P < 0.05) \). Using shoe walking as reference, the maximum flexion of the knee and the maximum peak of knee flexion in swing disappeared, but maintained the increase of knee flexion in stance \( (p < 0.01) \). The PLS caused mild knee hyperextension \( (P < 0.05) \), but the increase in maximal knee flexion moment was not found to be statistically significant. Comparing with BF, increased the hip flexion moment in stance. Hip flexion at initial contact, hip rotation angle at toe-off, as well as maximal hip power absorption in stance, deviated significantly more from normal data in PLS compared to barefoot \( (P < 0.01) \). When compared with shoe walking, it was demonstrated a change in the hip rotation angle at toe-off \( (p < 0.01) \). An increase in hip energy generation was also observed, but it was not statistically significant. The orthosis led to a further increase in the already high range of pelvic motion in the sagittal plane \( (P < 0.05) \) when compared to barefoot, however this sagittal range of motion was too large for these devices as well as for barefoot. (Desloovere 2006)

B) Results comparing with other orthosis configuration: the PLS produced a slightly more normal ankle moment and power absorption at loading response \( (P < 0.05) \). Although both orthoses led to increased knee flexion velocity at toe off \( (P < 0.05) \), the effect of the PLS was significantly higher compared to the CFO \( (P < 0.01) \). The PLS also led to reduced knee flexion at initial contact and a slightly hyperextended knee in stance \( (P < 0.05) \). The PLS was associated with further increase in maximal hip abduction moment in stance \( (p < 0.05) \). (Desloovere 2006)

4.2.5 Sensitivity of GMFM88:

Utmost suitable children were in GMFCS levels III \( (36.2\%) \) and IV \( (29.6\%) \), followed by level I \( (15.6\%) \), level II \( (13.2\%) \) and level V \( (5.4\%) \). Participants charged with AFOs only were mainly in GMFCS levels I \( (30\%) \) and III \( (33.7\%) \), whereas children wearing AFO devices plus aids were predominantly in levels III or IV. The
two groups showed next data, AFO only (GMFCS levels I to IV) and AFO plus aids (GMFCS levels II to V). The mean GMFM-88 total score in the 191 assessments with aids and/or orthoses is 59.4, with the higher dimension score in dimension D (Standing; 36.5) and the lower dimension score in dimension E (Walking, Running, and Jumping; 23.4). The same pattern could be seen for each subgroup: AFOs only \(n=86\), and AFO plus aids \(n=76\). The mean change from unaided to aided assessments showed a significant improvement for all groups, with the largest change in the standing dimension of the GMFM 88.

Children in level V wore the devices in order to prevent contractures and deformities, rather than to ameliorate purpose.

The magnitude of variation from BF function to function wearing an orthotic configuration was largest in Dimension D for children in GMFCS levels I to IV but only statistically meaningful for participants in levels III and IV. The versatility of the alteration in Dimension D was large for children in levels I and II, with some people showing contravening change or decreased function when wearing their orthoses for items in the Standing Dimension of the GMFM-88. Dimension E showed significant improvement for children in GMFCS levels I to IV. The total GMFM-88 score demonstrated implicative betterment for levels I, III, and IV but not for children in level II. (Russel 2005)
<table>
<thead>
<tr>
<th>Type of AFO design</th>
<th>Stride length and cadence</th>
<th>Initial contact</th>
<th>Kinematics and kinetics</th>
<th>Energy cost and oxygen consumption</th>
<th>Recommended for:</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAFO</td>
<td>Increases stride length and decreases cadence compared to no brace (17%), so the velocity is slower</td>
<td>A diminution of plantar flexion is found</td>
<td>Data no provided</td>
<td>Data no provided</td>
<td>Independent walkers (level I-II in GMFCS)</td>
</tr>
<tr>
<td>HAFO</td>
<td>Increases step and stride length and decreases cadence (13%), so the velocity is slower</td>
<td>Increases the extensor moment of the knee</td>
<td>Showed a higher increase in peak dorsiflexion during stance. Presented a later timing of peak dorsiflexion in stance.</td>
<td>Lessened</td>
<td>Data no provided</td>
</tr>
<tr>
<td>SAFO</td>
<td>Increases step and stride length and decreases cadence (13%), so the velocity is slower</td>
<td>Observed a decrease of plantar flexion</td>
<td>Less increase in peak dorsiflexion than HAFO. And the timing of the same peak was earlier than in HAFO. Decreased peak power generation in stance</td>
<td>Reducted in fast walking</td>
<td>Gain knee and hip motion</td>
</tr>
<tr>
<td>PLS</td>
<td>Increases step and stride length and decreases cadence (11%). In fast walking an increase of velocity is observed.</td>
<td>Cause a level knee hyperextension</td>
<td>Improve first and second rocker of the ankle. Plantar flexion moment during push-off is increased. Impact absorption in the knee is raised. Also maximum flexion of the knee tends to change in stance and swing phases. Hip flexion in stance is better. Intensification of internal rotation and abduction in hip motion.</td>
<td>Declined; O₂ consumption was not significant because the small increase of velocity</td>
<td>Data no provided</td>
</tr>
</tbody>
</table>

Table 6. Synthesis of the results
5. Discussion

The articles used in this review investigated the effectiveness of different types of AFO braces for different types of cerebral palsy. The interventions included were: SAFO, DAFO, HAFO and PSL.

The comparison between the six different studies, in order to opt for the most effective, is complicated due to the variety of different interventions and trial methodology. Moreover, the number of items of sufficient scientific relevance is very poor and many of them are not full text available, complicating our review. In order to improve the revision for a possible researcher that comes after me, I think it is important to mention that some papers were not accessible in databases, so it was necessary to contact the authors, sometimes we obtain them, but in certain cases was not possible, because they did not answer or because the information facilitated by the databases was incorrect.

As an additional limitation we can also refer that the authors chose different methods to evaluate the participants. Only three of them preferred the GMFCS (Bjornson 2006, Russel 2005 and Buckon 2004), while the others used EMG or gait analysis. This made it difficult for us when putting the results of the different studies in common. It would be more appropriate to use several tools of evaluation instead of a single one, so that they would have been more likely to coincide and get more data facilitating our work.

Another restriction that we found was the fact that each article did not compared the AFO device with other/s, or with barefoot condition, because once again it hinders the work of gathering information. If we take Desloovere 2006 article as model, we see that the information is much more comprehensive and complete, because the study compared the brace in question with another, besides comparing it to being in barefoot condition. Given so, we think it would be interesting to extend the line of research in future studies, although we understand that might have been due to time limitation.

Regarding the methodology of the selected studies, we found several limitations that are at least controversial. Two of them (Radtka 1997, Buckon 2004 and Desloovere 2006) had a very small number of participants, less than twenty, possibly due to lack of
funds or lack of volunteers with the characteristics that define the studies to trial participants. In this case, we encourage professionals working in this field of pediatrics to start working on durable investigations. They have to work with large groups of children with these characteristics and spend tones of time with them, because unfortunately the treatment of these children is hard and long.

Regarding the duration of the treatment, we think that in some cases it is very restricted. In this branch of physiotherapy, we think short-term effects are important, but also long-term effects and maybe more. Therefore, we consider that the duration of the study should comprise a longer period. On the other hand, two of the articles, Desloover 2006 and Dong-wook Rha 2009, do not provide this information, and we think it is essential to take into account when presenting the outcome.

We also think it's important having into account the opinion of the family and those around the child, even the children themselves (depending on their capabilities), because they are the ones who will work with the orthotic devices and will notice the improvement on a daily basis. On the other hand, according to our limited experience, we think sometimes it is better if parents pass some scales or some items of them, as the children try to distort sessions striving perhaps more with therapist, and with their parents are acting normally.

We find of utmost importance for next studies to consider the following aspects: the pain suffered by participants, any erosion these devices may inflict on the skin, the scope of any muscle weakness, and whether they interfere or not in the proprioception of the wearer. Most of the patients diagnosed with cerebral palsy, present a serious affection that causes a serious impact at the time of carrying out the language. Therefore, it would be recommendable that the people, who valuate the different braces, as we explained earlier, are those close to the children themselves, as they comprise expressions to perfection and know how to identify what children want to tell, either with facial expressions, different cries or so. Students and professionals that have worked with children that wear braces know how important it is the making of the splint and cast, plus revisions according to the child's growth. As the orthoses are usually made by hard plastic material, in the event of presenting a poor adaptation to the child's foot it can cause erosions and originate a rejection of the brace, thereby not achieving any benefit from the positive factors. With respect to the previously referred muscular
weakness, we feel the valuation is very important, because many orthotic devices give such restraint that limit muscular work, which in turn can cause hypotonia. Therefore we believe it is very relevant and useful to use a brace to allow the normal muscles work, because strong muscles can give stability and subjection to the joints, thus decreasing possible associated pathologies.

Finally, and not least important, we find of particular interest the issue of the relationship between price, and quality and the factor mentioned hereinabove. None of the articles referred to the cost of these AFO braces, which we certainly know that they are not cheap. We are in a time of economic crisis and with so many aids being suppressed, we would have to assess whether children really benefit of these configurations prior to recommending its use. For example, in the event of the DAFO devices which are nowadays fashionable, and many children wear them without being beneficial to them or even regardless of the child's growth, it might happen that in a few months and because of the absence of any benefit deriving there from they will have to use another devise and re-spend their money again. So in our point of view we think that this is a very important and relevant aspect to consider.

In summary, the AFO braces mentioned in this study are beneficial for step and stride length, and also for decreasing cadence. Changes in kinetics and kinematics are found, normally gaining in maximum peaks and moments, affecting also the initial contact moment even in the plantarflexion and in the knee extension. The energy expenditure and the oxygen consumption is lower with the use of the braces. To conclude, we can also underscore that the DAFOs are recommended for independent walkers, the SAFOs are primarily intended to gain hip and knee motion, and finally with respect to the other two no information is available in this regard.
6. Conclusion

The use of AFO enhances the functional abilities of children with CP, in addition to improvements in gait parameters, in kinetic and kinematics factors, in joint motions and oxygen and energy expenditure. This is considered a higher quality of life in the population suffering from some of this disease, because of its high incidence in society.

It is recommended that for future research in this area, studies with a larger sample and longer intervention should be addressed, intended to gather more evidence on its effectiveness.

It is also advised to highlight in articles whether there are side effects after these interventions, so as not to cause doubt on their use, even if they are effective. In addition, we recommend future studies on a single type of brace, because mostly what was found were comparative studies, and this suggested approach would allows us to get enough information on each type of brace.

On the other hand, it would be helpful to make studies which analyze the effectiveness of treatments with scales on the quality of life, together with additional studies that compare the level on a scale with and without the braces, with the intention of demonstrating to participants and those around them the benefits of the rehabilitation.
7. References


11. Rut Barenys, Lourdes Macias, Alicia Manzanas. Uso de las férulas, splints y ortesis para las extremidades inferiores. Revisión de la literatura sobre la eficacia en niños con trastornos neurológicos.SEFIP.


19. www.dafo.com
8. Appendix

Appendix 1

a) HAFO  

b) PLS  

c) SAFO

Appendix 2

Free plantar flexion DAFO
Appendix 3

Plantar flexion stop DAFO

Appendix 4

The Gross Motor Function Classification System (GMFCS) is a 5 level classification system that describes the gross motor function of children and youth with cerebral palsy on the basis of their self-initiated movement with particular emphasis on sitting, walking, and wheeled mobility. Distinctions between levels are based on functional abilities, the need for assistive technology, including hand-held mobility devices (walkers, crutches, or canes) or wheeled mobility, and to a much lesser extent, quality of movement.
Appendix 5

The following table in your review, shows the classification of levels of evidence for group studies that the AACPDM uses in its reviews. In descending order, the designs are increasingly able to demonstrate that the intervention—and not something else—was responsible for the observed outcome. Level I evidence is the most definitive for establishing causality, with greatest reduction in bias. Level IV can only hint at causality; Level V only suggests the possibility.

<table>
<thead>
<tr>
<th>GMFCS Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I</td>
<td>Children walk indoors and outdoors and climb stairs without assistance. Children perform gross motor skills including running and jumping, but speed, balance and coordination are impaired.</td>
</tr>
<tr>
<td>Level II</td>
<td>Children walk indoors and outdoors and climb stairs holding onto a railing or experience 4-wheelers walking on uneven surfaces and inclines and walking in crowds or confined spaces.</td>
</tr>
<tr>
<td>Level III</td>
<td>Children walk indoors or outdoors on a level surface with an assistive mobility device. Children may help stairs holding onto a railing. Children may propel a wheelchair manually or are transported when traveling for long distances or outdoors on uneven terrain.</td>
</tr>
<tr>
<td>Level IV</td>
<td>Children may continue to walk for short distances on a walker or rely more on wheeled mobility at home and school and in the community.</td>
</tr>
<tr>
<td>Level V</td>
<td>Physical impairment restricts voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Children have no means of independent mobility and are transported.</td>
</tr>
<tr>
<td>Level</td>
<td>Intervention (Group) Studies</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>I</td>
<td>Systematic review of randomized controlled trials (RCTs)</td>
</tr>
<tr>
<td></td>
<td>Large RCT (with narrow confidence intervals) (n &gt; 100)</td>
</tr>
<tr>
<td>II</td>
<td>Smaller RCT’s (with wider confidence intervals) (n&lt;100)</td>
</tr>
<tr>
<td></td>
<td>Systematic reviews of cohort studies</td>
</tr>
<tr>
<td></td>
<td>“Outcomes research” (very large ecologic studies)</td>
</tr>
<tr>
<td>III</td>
<td>Cohort studies (must have concurrent control group)</td>
</tr>
<tr>
<td></td>
<td>Systematic reviews of case control studies</td>
</tr>
<tr>
<td>IV</td>
<td>Case series</td>
</tr>
<tr>
<td></td>
<td>Cohort study without concurrent control group (e.g. with historical control group)</td>
</tr>
<tr>
<td></td>
<td>Case-control Study</td>
</tr>
<tr>
<td>V</td>
<td>Expert Opinion</td>
</tr>
<tr>
<td></td>
<td>Case study or report</td>
</tr>
<tr>
<td></td>
<td>Bench research</td>
</tr>
<tr>
<td></td>
<td>Expert opinion based on theory or physiologic research</td>
</tr>
<tr>
<td></td>
<td>Common sense/anecdotes</td>
</tr>
</tbody>
</table>