Case Report

The Effect of gait training with Hip Orthosis on Gait Parameters in a Cerebral Palsy Crouch Gait: a case study

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ABSTRACT:
Purpose State: Cerebral Palsy (CP) is a neurological disorder that occurs while the brain is under development [1]. This situation alters gait parameters. To improve gait parameters in children with CP and crouch gait pattern, we designed a new reciprocal hip orthosis and evaluated its effects on spatial-temporal parameters and gait kinematics.

Method: Through a case study the new hip orthosis was evaluated on a 15-year-old girl with CP and crouch gait pattern. Spatial-temporal and kinematic data were captured by a 6-Camera Vicon digital motion capture system in three conditions: baseline (condition A), immediately with orthosis (condition B), and without orthosis after 12 sessions of gait training using new hip orthosis (condition C).

Results: Comparing condition A and C, walking with the new hip orthosis improves step length, and velocity on the right side but the left side did not change remarkably. Symmetry ratio between left and right sides in step length and velocity increased %33.33 and %4.95 respectively. Also this new hip orthosis decreased flexion and increased extension in hip and knee joints through gait.

Conclusion: Gait training with the new reciprocating hip orthosis improved spatial-temporal and kinematic parameters on a child with CP and crouch gait pattern.

Keywords: cerebral palsy, crouch gait, gait training, orthosis

INTRODUCTION
Cerebral palsy (CP) is a neurological disorder that occurs while the brain is under development [1]. It is the most common cause of physical disability in children worldwide [2]. Gait dysfunction is one of the problematic concern in this type of children resulting from primary (neural system damage), secondary (muscle and bone deformity) and tertiary compensation (in order to adjust with primary and second problems) disorders [3]. However, many children with CP are able to walk independently, but their gait characteristics are different compared with normal gait [4]. Several gait deviation patterns have been categorized among children with CP [5], of which crouch gait is one of the most prevalent. Totally 69% of
children with CP (74% of those with diplegia and 88% with quadriplegia) walked with crouch gait pattern [6] and gait symmetry usually has not seen in these children. Differences between left and right sides of motor involvement cause asymmetry in temporal-spatial gait parameter as well as gait appearance. In crouch gait pattern, hip and knee joints are in flexion and ankle joint is in dorsiflexion [5]. This situation is usually incorporated with hip adduction [7]. These changes may lead to alter the walking parameters such as decreasing stride length, cadence and speed of walking and foot clearance [3] which may increase energy expenditure and patellofemoral force [8,9]. Crouch gait also may change orientation of body parts (in relation with each other); therefore reducing their muscles ability to generate extension moment in hip and knee joints. These changes are seen especially in hip extensor muscles and create a vicious cycle in hip joint extension [10] consequently, produce flexion in knee and dorsiflexion in ankle joints. Therefore, lines of gravity moves in front of the hip and back of the knee, and therefore quadriceps muscle have to generate more contractile force to prevent knee flexion during walking which cause knee pain over time. This situation may be worsened if an appropriate rehabilitation program is not implemented [11]. Gait rehabilitation programs in subjects with CP are based on three basic approaches including conventional over ground gait training, manually assisted body weight supported treadmill therapy and robot assisted or driven gait orthosis. The first approach is based on neurodevelopmental therapy theory and second and third on neuroplasticity theory [12]. In neurodevelopmental therapy theory assumed that it is necessary to achieve some “building blocks” to perform a complex task. For example, therapists work on standing, weight shift and muscle strengthening to prepare patient for gait [13]. Those therapies were performed in parallel bar using different types of orthosis -if necessary- and support from therapists. But current concept of motor learning and neuroplasticity emphasize the repetitive task-specific training to improve function [14]. To achieve this goal, driven gait orthosis was designed and developed recently to provides patients more task-specific training and more repetition with less help from therapists [13]. According to some studies, it can improve gait performance in spinal cord injury and stroke adult patients [15-19]. Borggraef et.al evaluated Robotic-Assisted Treadmill Training(RATT) on children with CP and reported GMFM improved after three weeks [20] and also improvement in GMFM has been demonstrated in gait disorder of children when using locomotor training by Meyer-Heim et. al [21]. Despite of the evidence that shows efficacy of driven gait orthosis, Druzbicki et. al explained that walking with gait trainer using external power may change the active gait training to passive movements especially in children [12]. Also, they are expensive and need a large space, so can be used only in clinical setting. Using treadmill and body weight support in robotic assisted gait trainers may eliminate balance reactions in patient which is one of the primary requirements for walking. With concern the above limitations, a new hip orthosis (Rayan) was developed in University of Social Welfare and Rehabilitation Sciences to provide a portable, chip, mechanical gait trainer for children with CP. The concept of design is based on coupling both hip joints in order to correct each leg pattern using another leg movement through gait and simultaneously eliminate concurrent hip flexion to avoid crouch posture. The aim of this study was to evaluate the influence of gait training with this orthosis on gait parameters in a child with CP and crouch gait pattern. It was assumed that orthotic gait training with this new hip orthosis has possitive effect on gait parameters and may improve walking of this child.

METHOD
Participant’s description
A volunteer (15-year-old girl, weight: 50 kg; height: 152 cm) diagnosed as spastic diplegia CP with crutch gait pattern and normal intelligence quotient participated in this study after signing consent form. She had no history of Botox injection or bone or tendon surgery and using any orthosis in last three years. She had no contracture or severe bone deformity and was not obese and her passive range of motion in lower extremity was normal. She had received physical and occupational therapy from her childhood until beginning intervention. Physical assessment showed she had no muscle in lower extremities with spasticity more than 2 in modified Ashworth scale. She was able to walk independently without assistive devices (Gross Motor Function Classification System II). The study was approved by the Ethics committee of the University of Social Welfare and Rehabilitation Sciences, Tehran, Iran 2015.

**Intervention**

The new hip orthosis (Rayan) consists of a plastic pelvic basket, two thigh shells and two hip joints which are connected by a cable (Figure 1). Hip joint was designed to prevent simultaneous flexion in 0 degree position. Hip flexion on the right side creates double power and half range of motion of extension in the left hip joint and vice versa.

A spring is embedded distally from each hip joint to assist hip abduction. The pelvic basket and thigh shells were specifically fabricated from poly-propylene sheet (4 mm thickness) by molding for the child and then the new mechanism of hip joint was added to the pelvic basket and incorporated into the orthosis.

**Experimental protocol**

The participant was invited to the laboratory and spatial-temporal and kinematic data were captured by 6-Camera Vicon digital motion capture system (Oxford Metrics, Oxford, UK) using a frequency of 100Hz in three conditions: baseline (condition A), with orthosis, after 20 minutes of gait training by Rayanorthosis in laboratory environment (condition B), and without orthosis, a day after 12 sessions of gait training with the new hip orthosis (condition C). The subject walked through six meters walkway in front of Vicon cameras. Three trials used for each condition. During the examination, the child was allowed to rest when it was necessary. Gait training included 20 minutes walking with the orthosis along with routine physical therapy program during four weeks by an expert physical therapist in safe clinical environment. Fifteen retro-reflective markers were used on the lower extremity. The markers were placed bilaterally over the sacrum, both anterior superior iliac spines (ASIS), greater trochanter, and the lateral condyle of the femur, the head and lateral malleolus of the fibula, the second metatarsal head, and calcaneus. Three windows were cut out in pelvic basket in both ASIS and sacrum area to let markers attach to body, directly. All markers placement were done by an expert person. Step length, velocity and kinematics of right and left lower limb were analyzed by MATLAB software version 7.10.0.499 (R2010a).

**RESULTS**

Table 1 shows the spatial-temporal and symmetry data in each condition for right and left extremities. The results showed that step length and velocity were increased %28.66 and %3.84 on the right side, but these parameters on the left side
was not changed remarkably (%-6.7 and %0.0), when condition A compared to condition C. To assess symmetry for step length and velocity variables, a symmetry ratio index calculated by dividing the mean of these values on the left side by the mean values on the right side. When symmetry ratio closes to 1, it shows maximum symmetry in the variable [22].

**Table 1**: spatial-temporal parameters in conditions A (baseline), B (immediately with orthosis) and C (after 12 session of gait training evaluated without orthosis)

<table>
<thead>
<tr>
<th></th>
<th>Condition A</th>
<th>Condition B</th>
<th>Condition C</th>
<th>Improvement percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>side</td>
<td>right</td>
<td>left</td>
<td>right</td>
<td>left</td>
</tr>
<tr>
<td>Step length(cm)</td>
<td>85.23</td>
<td>17.89</td>
<td>87.34</td>
<td>22.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Symmetry ratio of Step length (L/R)</td>
<td>0.21</td>
<td>0.25</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>Velocity(m/s)</td>
<td>0.52</td>
<td>0.55</td>
<td>0.39</td>
<td>0.35</td>
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<td></td>
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<tr>
<td>Symmetry ratio of Velocity (L/R)</td>
<td>1.06</td>
<td>0.89</td>
<td>1.01</td>
<td></td>
</tr>
</tbody>
</table>

Improvement ratio of step length and velocity was %33.33 and %4.95, respectively which calculated by below formula.

**Improvement percentage**

$$\text{Improvement percentage} = \frac{\text{Condition C} - \text{Condition A}}{\text{Condition A}} \times 100$$

Figure 2 demonstrates hip and knee flexion/extension and ankle dorsiflexion and plantar flexion in each condition. There was an improvement in hip and knee pattern in condition B and C compare with condition A.

**Figure 2**: Sagittal plane kinematic plots of hip, knee and ankle in left and right sides
DISCUSSION
In this study a new hip orthosis was evaluated in a child with CP. This device was able to assist hip abduction and also prevent simultaneous flexion in hip joints. In this new hip orthosis, flexion on one side created extension on the other side with twice the power and half range of motion. The result of a previous study was a foundation of the 2:1 flexion-extension ratio in this new design [23]. The results demonstrated that using this orthosis improved gait spatial-temporal parameters in lower limb joints. This study evaluated ted Step length and velocity an also gait symmetry as secondary outcomes. The results demonstrated that, symmetry in those variables improved, which are useful indicators in rehabilitation and clinical setting [24]. This study may claim that using reciprocal hip orthosis could improve symmetry by coupling two legs.

In condition B, when subject walked with the new reciprocal hip orthosis, graphs shows an increase in extension and decreased in flexion angles in hip and knee joints. These improvements was deducted but still exist in condition C which subject walked without the orthosis. Ankle joint graphs in condition B also shows a decrease in dorsiflexion. In condition C, the right ankle, which had more dorsiflexion in base line, improved after 12 sessions of intervention (Figure 2). These short term effects of Rayanorthosis may have potential to improve gait pattern in long term. Biomechanically, crouch gait alters body segment orientation and changes dynamic coupling between joints thus reducing the capacity of important hip and knee extensory muscles in stance phase which may be seen in condition B. Extensor muscles capacity of Gluteus Maximus, posterior part of Gluteus Medius, Vastus and Soleous decrease in crouch gait and this reduction is different from their physiological capacity.Decreased extensor muscle capacity along with increased gravity lever arm induces more hip and knee flexion which may lead to increased crouch gait by creating a downward cycle [10]. The new orthosis prevents double hip joint flexion and improves crouch posture. Also, the reciprocating flexion-extension movement pattern of the Rayanorthosis may modify muscles alignment and also their origins and insertions orientation; therefore, it can improve extensor muscles capacity. Moreover, the abduction assist spring in the new device helps to provide abduction and may prevents hip adduction which can collaborate in gait improvement. Subsequently, reduction in hip adduction angle might be caused to increase the base of support and improve balance and stability. However, these parameters were not evaluated in this study. Neurologically, some authors believe that intensive and repetitive task specific training in children with CP improves their ability to walk which this is supported by the neuroplasticity theory which may seen in condition C. According to this theory, some studies used RATTto achieve this aim. Scientists have announced that walking can be improved by using external devices [25] however, in a recent study, Druzbiicki and colleagues reported that a powered external device such as Lokomat may makes the children movement passive and decreases effectiveness of these kinds of devices [12]. While the results of this study on gait parameters improvement in this child after 12 sessions of gait training was in the line with the results of other studies those using RATT. But, this device may make active movement by using her own muscles without any external power, thus may be more effective than RATT. Mechanical characteristics of this new hip orthosis with low weight and bulk may be also another advantages of this device compared with of RATT, but we did not compare these two devices in this study. Future studies should aim at comparing these two.

Only one child was evaluated in our study, thus it is suggested to evaluate more children with different gait patterns and other neurological disorders using this new orthosis. Also, it is suggested to compare this new orthosis with other kinds of orthosis such as AFOs and SWASH and even with RATT. Other parameters such as
stability and gross motor function can be affected by using this new orthosis which was not examined and it could be evaluated in future studies.

CONCLUSION
An improvement of gait spatial-temporal parameters and hip, knee, and ankle joints were seen when one child with diplegic CP used the new hip orthosis. Also, gait training with Rayanorthosis, improved gait parameters even without using the orthosis. Further evaluation is needed to assess the effectiveness of this new hip orthosis.

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REFERENCES
16. Mayr A, Kofler M, Quirbach E, Matzak H, Fröhlich K, Saltuari L. Prospective, blinded, randomized crossover study of gait rehabilitation in stroke patients using the


