The aim of the current study was to investigate whether children with CP show a setback to primitive arm postures during walking as well. It may be possible that they adopt primitive arm postures during walking similar to those seen in newly walkers. Therefore, we studied the kinematics of the arms during walking at a self selected speed in 11 children with hemiplegia, 15 children with diplegia and 24 healthy control children, and whether the arm posture changes in these children when they are walking at a high speed. We found that children with CP hold their hands more anteriorly and elevated, while their upper arm is rotated more posteriorly compared to the control children. Children with hemiplegia show a more elevated posture of the hemiplegic arm compared to the unaffected arm. The increase in walking speed further accentuated the differences between the groups for the hand elevation. These findings indicate that children with CP show a setback to more primitive arm postures during walking comparable to newly walkers.

INTRODUCTION
Children who are learning to walk, do not adopt a natural reciprocal arm swing as in adults until they reach the age of one and a half years [1]. During the first ten weeks of gait they hold their arms in fixed “guard” positions [2]. During gait maturation, they gradually lower the fixed position of the arms from a high guard (external rotation at the shoulder and flexed elbows with the hands at shoulder level) to a low guard position (arms extended along the body with no noticeable movement). Finally, they progressively start to move the arms during walking.

Children with Cerebral Palsy (CP), on the other hand, show affected motor control with an associated pathological gait pattern due to injury to the central nervous system in the developing brain [3]. This central nervous system damage is accompanied by the persistence or delayed disappearance of primitive reflexes [4]. Since children with CP show this setback to primitive reflexes and patterns, it may be possible that they adopt primitive arm postures during walking as well. The aim of the current study was to investigate whether children with CP show a setback to primitive arm postures during walking similar to those seen in newly walkers, and if so whether both arms participate equally in this altered posture. In addition, we were interested to know whether spasticity of the arm muscles also has an influence on the arm posture presented in these children with CP (especially in children with hemiplegia). Thus, we studied the effect of an increase in walking speed on the arm postures used in these children with CP.

METHODS
Eleven children with hemiplegia (HE: age 7.83 ± 2.98 years, weight 23.9 ± 7.6 kg and height 1.22 ± 0.15 m), 15 children with diplegia (DI: age 9.96 ± 2.47 years, weight 31.5 ± 13.4 kg and height 1.34 ± 0.19 m) and 24 typically developing control children (TD: age 9.40 ± 2.16 years, weight 31.7 ± 8.6 kg and height 1.38 ± 0.14 m) participated in the experiment. Children with CP were included if they were independent walkers, were diagnosed with predominately spastic type of CP, did not show ataxia, did not receive Botulinum toxin A treatment within the past 6 months or did not undergo orthopedic surgery. Subjects were asked to walk at a self-selected speed (FW) and as fast as possible without running (FFW) along a 10-meter walkway in a straight line. 3D gait kinematics were recorded using an 8-camera Vicon system with the total body Plug-In-Gait marker set. Three trials were assessed for each subject for both speed conditions.

Three measures were calculated to assess the participants’ arm posture. (1) Mean position of the hand marker in the sagittal plane over the gait cycle along the vertical axis, (2) average displacement of the hand marker over the gait cycle in the sagittal plane along the horizontal axis, and (3) average angular displacement over the gait cycle of the upper arm segment with respect to the vertical. The correction for whole body up and down movements (important for (1)) and for forward motion (important for (2)) consisted of subtracting the displacement along the same axis of the L5 marker (the spinous process of the fifth lumbar vertebra) from the time-courses of the displacement of the hand. To take into account size differences, the first two variables were normalized by dividing them by the subjects’ height. To compare the three groups, we used a general linear model with group as a factor, two repeated measures factors (walking condition and side of the body) and walking speed as a covariate.
RESULTS AND DISCUSSION

There were significant differences in walking speed (FW: TD: 1.20 ± 0.16 m/s vs HE: 1.10 ± 0.13 m/s, p=0.81; TD vs DI: 0.94 ± 0.24 m/s, p=0.013; FFW: TD: 2.00 ± 0.17 m/s vs HE: 1.67 ± 0.18 m/s, p=0.007 TD vs DI: 1.41 ± 0.41 m/s, p<0.001) and height (HE<TD, p=0.02) but not in age (p=0.09) and mass (p=0.09) between the groups.

Table 1 presents the data of the mean vertical hand position during the gait cycle. The statistically significant results are discussed below. The data clearly shows that both CP groups presented a vertical hand position that was more elevated compared to the TD children (table 1: group). In children with hemiplegia the most affected hand was held higher during walking than the least affected hand (table 1: side*group). When the subjects walked at a higher speed the vertical hand position showed a higher increase in the two CP groups compared to the TD children (table 1: cond*group). The vertical hand position in HE children on the most affected side increased much more when walking speed increased compared to that on the least affected side (table 1: side*cond*group). A high guard position is characterized not only by the hands being higher but also by them being more anterior. It was found that CP children held their arms more in front of their body during walking compared to TD children, reflected by a significantly more anterior hand position (group: p=0.002; TD: 0.10 ± 0.03 versus DI: 0.15 ± 0.04, p<0.001; HE: 0.13 ± 0.04, p=0.021). A more anterior position of the hand can be due to the upper arm being held in front or behind the axis of the body. Hence we investigated the upper arm elevation angle in the sagittal plane. Both TD and CP children held their upper arm on average behind the vertical axis but the TD children held their arms less backwards (arm angle closer to the vertical) compared children with CP (group: p=0.001; TD: -9.23° ± 6.94 versus DI: -21.33° ± 10.88, p<0.001; HE: -15.82° ± 6.85, p=0.032).

CONCLUSIONS

During walking, children with CP appear to rely on arm postures comparable to newly walkers. The effect of the increase in walking speed on the most affected side in children with hemiplegia suggests that spasticity is an important contributing factor in the altered arm posture. Other factors related to biomechanical constraints due to higher walking speed (such as coping with instability) might also account for the altered arm posture in children with CP (especially for children with diplegia).

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REFERENCES

Table 1: Comparison of the mean vertical position of the hand (with respect to L5)

<table>
<thead>
<tr>
<th>Group</th>
<th>Side</th>
<th>Condition</th>
<th>Mean vertical position of the hand (% height)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>MA</td>
</tr>
<tr>
<td>TD</td>
<td></td>
<td></td>
<td>-10 ± .03</td>
</tr>
<tr>
<td>DI</td>
<td></td>
<td></td>
<td>-06 ± .05</td>
</tr>
<tr>
<td>HE</td>
<td></td>
<td></td>
<td>-06 ± .04</td>
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</tbody>
</table>

Group: averaged for side of the body and walking condition. Side*group: averaged for walking condition; most affected or non dominant (MA), least affected or dominant side (LA). Cond*group: averaged for side of the body; FW (preferred walking speed) and FFW (as fast as possible walking speed).