THE PASSENGER UNIT EXPENDS A SUBSTANTIAL AMOUNT OF TOTAL MECHANICAL WORK IN CHILDREN WITH CEREBRAL PALSY

1,2,3 Patricia Van de Walle, 1,4 Nele Op de Beeck, 1 Ann Hallemans, 1,4 Steven Truijen and 2,3 Kaat Desloovere
1 Department of Health Care, Artesis University College of Antwerp, Belgium
2 Clinical Motion Analysis Laboratory, CERM, University Hospital Pellenberg, Belgium
3 Department of Rehabilitation Sciences, Faculty of Kinesiology and Rehabilitation Sciences, Katholieke Universiteit Leuven, Belgium
4 Faculty of Medicine, University of Antwerp, Belgium
patricia.vandewalle@artesis.be

SUMMARY
Estimation of mechanical work by integration of the joint powers gives valuable supplementary information in evaluation of pathological gait. Total mechanical work of walking is increased in children with cerebral palsy (CP), compared to typical gait. This is due to an increase in work of both locomotor and passenger unit (head, arms, trunk). The amount of the passenger unit is about 10% of total mechanical cost in typical adult gait, slightly higher in typical pediatric gait and up to twice as high in children with diplegic CP.

INTRODUCTION
For the examination of the gait pattern, the body can be divided in two functional units: the locomotor unit and the passenger unit. The passenger unit consists of head, arms and trunk (HAT) and has minimal postural change in normal adult walking. In pathological gait, such as CP, however, the motions of the HAT often increase due to compensation strategies. These compensatory movements can compromise gait efficiency. Gait efficiency can be estimated by measurement of metabolic cost, but also by estimation of mechanical work. Estimation of mechanical work can be done by different estimation approaches, all based on the estimation of work from kinematics or kinetics: (1) calculation of external work, (2) sum of segmental energies and (3) integration of joint powers [1]. Estimation of the mechanical work by integration of the joint powers has the advantage that work can be defined separately for locomotor and passenger unit, thus allowing investigation of the individual contribution of both units to the total mechanical work. Until now, most evaluation of gait efficiency did not focus on, or even include the HAT into the estimations.

METHODS
Fifteen ambulatory children with diplegic CP, aged between 6.3 and 12.5 year (9.55±1.93 year), 14 typical adults between 20.9 and 35.2 year (26.21±4.16year) and 25 typical children between 5.2 and 12.4 year (9.30±1.93 year) received total body 3D gait analysis (Vicon, AMTI forceplates). For each subject 3 trials with valid bilateral kinetics were included. Mechanical work (Wj) was estimated by separate integration of positive and negative joint power profiles [J.kg⁻¹.s⁻¹] for neck, shoulders, elbows, wrists, waist, hips, knees and ankles as obtained from the Vicon Plug-in-Gait model. Mechanical cost (sum of positive and negative work, expressed per meter) was obtained by dividing work by stride length and was calculated separate for the locomotor unit (WjLU) and for the HAT (WjHAT). Total mechanical work was the sum of both (Wj = WjLU + WjHAT). Comparison between groups was done with one-way ANOVA with posthoc Bonferroni correction. Level of significance was set at 0.05.

RESULTS AND DISCUSSION
Total mechanical cost of walking was significantly higher in children with CP compared to adults as well as to typical children (figure 1). The increase in Wj was caused by an increase in both positive and negative work (figure 2).

Figure 1: Mechanical cost in typical pediatric and adult gait and in children with cerebral palsy. Total cost (Wj)= cost locomotor unit (WjLU) + cost passenger unit (WjHAT).
No significant differences in work were found between typical pediatric and typical adult gait. In children, however, the percentage of contribution of the HAT, was significantly higher and more variable than in adults. This is in line with previous findings that mechanical cost of walking is decreasing by increasing age and especially negative joint work does not reach adult values until the age of nine years [2]. The locomotor unit (HAT) expends significantly more energy in children with CP (table1). Wj_HAT expends 10±2% in adults, 13±4% in children with typical gait and 22±7% in children with CP. The small difference between children and adults with typical gait suggests that the increase in mechanical work in children with CP is related to pathology and not to age. Results suggest that part of the increased mechanical cost in children with CP is caused by excessive energy expenditure by the HAT. This increased mechanical work is probably caused by the compensatory movements of trunk and arms to maintain balance. Also the movements of the head contributes to a higher mechanical cost of the locomotor unit. As such, evaluation of pathological mechanical cost of walking should always include HAT.

CONCLUSIONS
Excessive mechanical cost in children with CP can be partly attributed to the passenger unit. The energy expended by the passenger unit is up to 2.5 times higher in children with CP compared to typical gait. Evaluation of the HAT should be part of future research as it can add supplementary information on causes of decreased gait efficiency in pathological gait that is useful in clinical practice.

ACKNOWLEDGEMENTS
This study was supported by grant (HA-G827) of the Artesis University College of Antwerp.
The authors like to thank the colleagues of the Clinical Motion Analysis Laboratory for their contribution to data collection and all the subjects for their willingness to participate!

REFERENCES

Table 1: Total mechanical work of walking (Wj) and mechanical work of walking for locomotor unit (Wj_LU) and passenger unit (Wj_HAT) in typical gait and in children with cerebral palsy. Percentage of the HAT in the total work. *: significantly different from adults; #: significantly different from children with typical gait; &: significantly different from children with cerebral palsy

<table>
<thead>
<tr>
<th></th>
<th>Wj</th>
<th>Wj_LU</th>
<th>Wj_HAT</th>
<th>Percentage HAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults (typical gait)</td>
<td>2.05 ± 0.40*</td>
<td>1.84 ± 0.36*</td>
<td>0.21 ± 0.07*</td>
<td>10 ± 2*c</td>
</tr>
<tr>
<td>Children (typical gait)</td>
<td>2.07 ± 0.31*</td>
<td>1.79 ± 0.25*</td>
<td>0.27 ± 0.11*</td>
<td>13 ± 4*c</td>
</tr>
<tr>
<td>Children (cerebral palsy)</td>
<td>3.24 ± 0.80c,b</td>
<td>2.50 ± 0.500b</td>
<td>0.74 ± 0.38b</td>
<td>22 ± 7b</td>
</tr>
</tbody>
</table>

Figure 2: Mechanical cost in typical pediatric and adult gait and in children with cerebral palsy: Total work is the sum of positive (Wj+) and negative work (Wj-).