Daily physical activity of schoolchildren with spastic diplegia and of healthy control subjects

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Objective: To assess the difference in daily physical activity between children with spastic diplegia and healthy schoolchildren, to determine whether special physical activity programs are needed in the population with cerebral palsy.
Design: Cross-sectional design.
Setting: Children's rehabilitation center Franciscusoord (day care center) and elementary schools.
Subjects: Children with spastic diplegia (5 boys; mean (±SD) age 8.0 ± 1.4 years; 9 ambulant, 1 wheelchair use) and healthy children (6 boys; mean (±SD) age 8.4 ± 1.0 years).
Measurements: Total daily energy expenditure (TEE) and sleeping metabolic rate (SMR) were measured by the doubly labeled water technique and a respiration chamber. The TEE/SMR ratio was used as an index for the level of daily physical activity.

Results: The TEE/SMR ratio under normal daily conditions in the children with cerebral palsy (mean ± SD): 1.56 ± 0.19 was significantly lower (p < 0.05) than in their healthy peers (mean ± SD: 1.83 ± 0.23) and was similar to the TEE/SMR ratio in a room-sized chamber.

Conclusion: Children with spastic diplegia are considerably less active than their healthy peers. We recommend special physical activity programs for these children. (J Pediatr 1995;127:578-84)

Disease often causes hypoactivity, which leads in turn to a reduction in functional ability and further hypoactivity. A tendency to fatigue and weak muscles is characteristic of spastic cerebral palsy. Directly measured maximal aerobic power of children and adolescents with CP is 10% to 30% lower than in control subjects. An excess of body fat in children with CP has also been reported. Hypoactivity may partly cause this decreased physical fitness, and sports programs might therefore be effective in children with CP. However, whether and to what extent hypoactivity is a problem in young children with CP is not clear. Because of the probably high physiologic stress of ordinary functional activities, such as ambulation, climbing stairs, and wheelchair driving, total daily energy expenditure in children with

<table>
<thead>
<tr>
<th>CP</th>
<th>Cerebral palsy</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFM</td>
<td>Fat-free mass</td>
</tr>
<tr>
<td>RMR</td>
<td>Resting metabolic rate</td>
</tr>
<tr>
<td>SMR</td>
<td>Sleeping metabolic rate</td>
</tr>
<tr>
<td>TBlw</td>
<td>Total body water</td>
</tr>
<tr>
<td>TEE</td>
<td>Total daily energy expenditure</td>
</tr>
<tr>
<td>TEE_{dlw}</td>
<td>TEE measured by doubly labeled water</td>
</tr>
<tr>
<td>TEE_{cal}</td>
<td>TEE in the indirect calorimeter</td>
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</tbody>
</table>

CP might be higher than expected from their activity pattern; it is possible that "relative" hyperactivity may exist. Adding physical exercise to the normal school activities and
### Table I. Characteristics of children with CP and healthy children

<table>
<thead>
<tr>
<th></th>
<th>Boys (n = 5)</th>
<th>Girls (n = 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>7.8 ± 1.6</td>
<td>8.4 ± 1.0</td>
</tr>
<tr>
<td>(6-10)</td>
<td>(7-10)</td>
<td>(7-10)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>125.5 ± 11.4</td>
<td>133.3 ± 5.7</td>
</tr>
<tr>
<td>(113-143)</td>
<td>(126-141)</td>
<td>(111-144)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>31.0 ± 9.3</td>
<td>27.8 ± 2.5</td>
</tr>
<tr>
<td>(20.2-47.4)</td>
<td>(25.9-32.7)</td>
<td>(20.1-38.5)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>19.2 ± 2.5</td>
<td>15.7 ± 0.9</td>
</tr>
<tr>
<td></td>
<td>(15.7-23.2)</td>
<td>(14.5-16.6)</td>
</tr>
<tr>
<td>TBW (L)</td>
<td>18.5 ± 4.4</td>
<td>18.2 ± 1.6</td>
</tr>
<tr>
<td>(13.0-25.0)</td>
<td>(16.9-21.1)</td>
<td>(14.2-18.7)</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>20.0 ± 5.8</td>
<td>13.6 ± 2.7</td>
</tr>
<tr>
<td></td>
<td>(14.2-30.7)</td>
<td>(8.3-15.6)</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>24.4 ± 5.8</td>
<td>24.0 ± 2.0</td>
</tr>
<tr>
<td></td>
<td>(17.1-32.9)</td>
<td>(15.4-23.4)</td>
</tr>
<tr>
<td>Sports (min/wk)</td>
<td>78 ± 79</td>
<td>126 ± 81</td>
</tr>
<tr>
<td></td>
<td>(60-180)</td>
<td>(60-240)</td>
</tr>
</tbody>
</table>

Values are mean ± SD, with ranges in parentheses.

*BMI*: Body mass index; *Sports*: organized sports activities (outside school).

*p < 0.05, significantly different between children with CP and healthy children.

**Therapy program** might then result in excess activity and consequently reduce the functional ability of the child.

Bandini et al. measured resting metabolic rate and TEE in adolescents with CP, using a ventilated hood and the doubly labeled water technique; they concluded that the ratio of TEE to RMR in nonambulatory CP subjects was significantly lower than in healthy control subjects. Systematic comparison of physical activity with that of healthy control subjects has not been done in young children with CP. Pre-adolescent children have much more leisure time, and it seemed important to evaluate whether lack of physical activity is also common among this age group. Therefore the aim of our study was to assess the difference in daily physical activity between children with spastic CP (diplegia) and healthy schoolchildren to determine whether specific physical activity programs are needed in the CP population.

**METHODS**

**Participants.** Five boys and five girls with spastic diplegia (legs and feet more affected than arms and hands; classification according to Hugberg [in Glow and Berg]) and 10 healthy children (5 boys) volunteered to participate. In 2 children the diplegia was combined with ataxia. Nine children with CP were ambulant; one used a wheelchair. Seven children with CP (with normal intelligence or mild mental retardation) were day students in the elementary school at a children's rehabilitation center, Franciscusoord; the other three children with CP (with normal intelligence) and all the healthy children were from elementary schools in and around Maassluis. All children were white and were between 6 and 10 years of age. The children and their parents were informed of all aspects of the study, and written consent was obtained. The study was approved by the medical ethics committee of the University of Limburg.

**Energy expenditure measurements.** TEE in normal daily conditions (TEE<sub>ND</sub>) was measured with the doubly labeled water (2H2<sup>18</sup>O) technique, which measures TEE during longer periods by assessing the difference in disappearance rates of two stable isotopes, 18O and 2H. Measurements were performed in the spring, between April and June, during a normal school period, according to the method described by Westerterp et al. Individually calculated doses (mixture of 5 atom percent; mixture of 5 atom percent 2H2<sup>18</sup>O and 10 atom percent 1H1<sup>18</sup>O), which were expected to create an excess of about 350 ppm 18O and 265 ppm 2H in the body water in the healthy children (3.9 gm per L body water) and about 300 ppm 18O and 150 ppm 2H in the children with CP (3.5 gm per L body water), were administrated orally to the children in the evening, after a baseline urine sample was collected. Different doses were given to the healthy children and the children with CP because in the course of the study we found that lower (and therefore less expensive) isotope doses were as accurate in the assessment of TEE as the originally used relatively high doses. To avoid spillage of isotope caused by oral motor problems (in children with CP), we gave the children a straw and asked them to drink the water slowly. After the dosage bottle was emptied, it was rinsed with 50 ml tap water, which was consumed through the same
Table II. TEE/SMR ratios in children with CP and healthy children in the respiration chamber (TEE_{chamber}/SMR) and under normal daily conditions (TEE_{body}/SMR)

<table>
<thead>
<tr>
<th></th>
<th>TEE_{body}/SMR</th>
<th>TEE_{chamber}/SMR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Ratio</td>
</tr>
<tr>
<td>Boys and girls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP</td>
<td>6</td>
<td>1.46 ± 0.14e</td>
</tr>
<tr>
<td>Healthy</td>
<td>10</td>
<td>1.47 ± 0.09</td>
</tr>
<tr>
<td>Boys</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP</td>
<td>5</td>
<td>1.46 ± 0.05</td>
</tr>
<tr>
<td>Healthy</td>
<td>5</td>
<td>1.46 ± 0.05</td>
</tr>
<tr>
<td>Girls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP</td>
<td>5</td>
<td>1.47 ± 0.12</td>
</tr>
<tr>
<td>Healthy</td>
<td>5</td>
<td>1.47 ± 0.12</td>
</tr>
</tbody>
</table>

Values are expressed as means ± SD.

*Significance: TEE_{body}/SMR ratio of these six children was (mean ± SD) 1.47 ± 0.07.
† Significance: TEE_{chamber}/SMR ratio for children with CP versus healthy children.
‡ Significance: TEE_{chamber}/SMR ratio versus TEE_{body}/SMR ratio for healthy children.

straw. In none of the children was loss of isotope observed. Further urine samples were collected on day 1 in the morning after the first voiding, and in the evening at 19 hours on days 1, 7, 8, 14, and 15. It was assumed that the children were in a steady state of body composition during the 2 weeks of measurement. Isotopes in the urine samples were measured in duplicate with an isotope ratio mass spectrometer (Aqua Sira, VG Isogas, Middlewich, Cheshire, England). The 18O analyses were reproducible within 0.4 ppm and 2H within 0.2 ppm. Excesses of 18O ranged from 304 to 348 ppm in the children with CP and from 261 to 423 ppm in the healthy children. Excesses of 2H ranged from 153 to 174 ppm (CP group) and from 185 to 285 ppm (healthy group). The mean TEE_{body} for 14 days was calculated with an estimated fixed respiratory quotient of 0.85 and the following equation 10: 

\[ rO_2 = \frac{N(2.078)(1.01)k_x - 1.04k_y - 0.0269r_{cor}}{rCO_2} \]

where \( rO_2 \) = CO2 production rate (in moles per day); \( rCO_2 \) = CO2 production rate (in moles per day); \( N \) = total body water (in moles); \( k_x \) = elimination rate 18O; \( k_y \) = elimination rate 2H; and \( r_{cor} \) = the correction factor for evaporative water loss, estimated by the formula \( r_{cor} = 1.05 N(k_0 - k_0) \).

TEE in laboratory conditions (TEE_{lab}) was measured in all the healthy children and in six children with CP (four boys) during a 24-hour stay in a respiration chamber. In four children with CP it was not possible to perform 24-hour measurements because they needed care or did not want to stay in the chamber for a day and night. The respiration chamber, 11 an open-circuit indirect calorimeter (14 m²), was furnished with a bed, chair, table, television set, telephone, intercom, and toilet. Air temperature was maintained at 20° C during the day and at 18° C during the night. The chamber was ventilated with fresh air at about 40 L/min. Volume of the outgoing air was determined by means of a dry gas meter (Schlumberger type G6, Dordrecht, the Netherlands), and gas was analyzed with a paramagnetic O₂ analyzer (Servomex type OA 184, Crowborough, England) and an infrared CO₂ analyzer (Hartman & Braun type URAS 3G, Frankfurt, Germany). An online microcomputer controlled the gas sampling system and calculated TEE_{lab} automatically according to Weir 12: 

\[ E (\text{kcal}) = 3.9 \times O_2 (\text{L}) + 1.1 \times CO_2 (\text{L}) \]

where \( E = \) energy expenditure, \( O_2 = \) oxygen consumption, and \( CO_2 = \) carbon dioxide production. To make the daily programs as uniform as possible, we scheduled activities such as board games, drawing, and watching television. Food was eaten as desired, but at fixed times, according to the normal diet.

Sleeping metabolic rate was measured in the 10 children with CP and the 10 healthy children in the respiration chamber from 3 to 6 AM when subjects were asleep.

Level of daily physical activity. The ratio of TEE to SMR was calculated and used as an index for the level of daily physical activity in the calorimeter (TEE_{body}/SMR) and under free-living conditions (TEE_{chamber}/SMR).

Body composition measurements. Body weight was obtained in the morning, before the children consumed any food or drink and while they were wearing underwear, with an electronic balance (August Sauter GmbH, Albstadt, Germany). Children with CP who were unable to stand upright were measured while sitting on a chair, with the same balance.

Height measurements were taken with subjects standing against a wall or, if unable to stand, while they were lying on a bed with a wooden T-square or a flexible tape.

Percentage of body fat was calculated from the mean total body water, measured by 18O and 2H dilution spaces. It was assumed that the 18O dilution space = 1.01 TBW and the 2H dilution space = 1.04 TBW, 13 and that water is 76% (boys) and 77% (girls) of the fat-free mass. 14
Statistical analysis. Data are expressed as mean ± SD. Comparisons between data were made with the Wilcoxon test for paired observations and the Mann-Whitney U test for unpaired observations (α = 0.05). Regression techniques were used to assess the relationships between SMR and FFM and between TEE_{dw} and FFM.

RESULTS
There were no significant differences in characteristics between the boys with CP and girls with CP (Table I). The healthy girls had significantly (p < 0.05) more body fat than the healthy boys. Body mass index in the boys with CP was significantly (p < 0.05) higher than in the healthy boys, whereas the difference in body fat between the boys with CP and the healthy boys was not statistically significant (p = 0.06). Girls with CP were significantly (p < 0.05) fatter than the healthy girls, but body mass index was similar in the girls in the two groups.

The SMR in the CP group ranged from 3.2 to 7.2 MJ/day and in the healthy group from 4.2 to 5.5 MJ/day. Mean SMR
did not differ between the groups (4.6 ± 1.3 MJ/day in the children with CP; 4.7 ± 0.4 MJ/day in the healthy children). Respiratory quotients during sleep were similar in the CP group (0.85 ± 0.05) and the healthy group (0.84 ± 0.06). TEE_{aw} in the CP group ranged from 5.0 to 10.2 MJ/day and in the healthy group from 6.9 to 11.3 MJ/day. On average, TEE_{aw} was significantly (p < 0.05) lower in the children with CP (7.0 ± 1.7 MJ/day) than in the healthy children (8.5 ± 1.3 MJ/day).

Figures 1 and 2 show, respectively, the SMR/FFM and TEE_{aw}/FFM relationships in both the children with CP and the healthy children. The lack of correlation in the healthy children is probably related to the narrow range in their FFM (Table I). Because regression points of the healthy children fitted well around the regression lines of the children with CP, one regression equation was calculated for the whole study population (healthy and CP children together) for the SMR/FFM relation (SMR = 0.20545 FFM + 0.0030129; r = 0.86, p < 0.001) and for the TEE_{aw}/FFM relation (TEE_{aw} = 0.30347 FFM + 0.94451; r = 0.73, p < 0.001). Because the x and y intercepts of these regressions did not differ significantly from zero, energy expenditure was divided by FFM to make comparisons between the children with CP and the healthy children. The SMR per kilogram of FFM was similar in both groups (0.21 ± 0.02 MJ/kg FFM per day in the children with CP and 0.20 ± 0.03 MJ/kg FFM per day in the healthy children). The TEE_{aw} per kilogram of FFM was 0.32 ± 0.03 MJ/kg FFM per day in the children with CP and 0.37 ± 0.06 MJ/kg FFM per day in the healthy children (p = 0.13).

Table II shows the calculated TEE/SMR ratios in the respiration chamber and under normal daily conditions. The TEE_{aw}/SMR ratio was similar in the children with CP and the healthy children. The TEE_{aw}/SMR ratio in the healthy children was 25% ± 17% (range 11.8% to +58.4%) higher (p < 0.05) than the TEE_{aw}/SMR ratio, whereas the TEE_{aw}/SMR and TEE_{aw}/SMR ratios in the six children with CP did not differ (1.47 ± 0.07 and 1.46 ± 0.14, respectively). The TEE_{aw}/SMR ratio ranged from 1.29 to 1.90 in the CP group and from 1.60 to 2.36 in the healthy group, and was on average 15% lower (p < 0.05) in the CP group than in their healthy peers. The lowest TEE_{aw}/SMR ratio (1.29) was found in the nonambulant child with CP. The TEE_{aw}/SMR ratio of the nine ambulant children with CP was 1.59 ± 0.18 and was significantly (p < 0.05) lower than the TEE_{aw}/SMR ratio of the healthy children. Four children with CP had TEE_{aw}/SMR ratios within the range of ratios in the healthy children.

DISCUSSION

Height and weight of the healthy children in this study are representative of those in the Dutch population.15 The children with CP tended to be smaller and were fatter than their healthy peers, in agreement with previous reports.4,5,6 Because of the relatively long interval between the administration of the doubly labeled water and the urine sampling (12 to 14 hours), body fat as determined from TBW may be an underestimate of the actual body fat because of gradual dilution of the isotope enrichment.17 However, in healthy adults the overnight protocol has been shown to give the same results as hydrodensitometry.17

Both children with CP and healthy children had gymnastic or swimming lessons at school, on average, twice a week (for 45 minutes). Although there are no reference values regarding organized sports activities in The Netherlands, we have no indications that the level of sports activities of the group of healthy children differed from the norm.

The intercepts of the SMR/FFM relation in our study did not differ from zero, in agreement with findings of Weinsier et al.18 in healthy infants and preschoolers. The SMR (in absolute units and per kilogram of FFM) did not differ between the CP group and the healthy group. Therefore the increased tone of spastic muscles, which also exists during sleep,19 has no measurable effect on SMR. Wakah et al.20 measured basal metabolic rate in 11 children with different types and degrees of spasticity. In 9 children, energy expenditure was far below the value expected for their age. Bandini et al.5 found a significantly lower RMR in adolescents with spastic quadriplegia than in control subjects. However, metabolic rates in both the study of Wakah et al. and Bandini et al. were not normalized for body size and composition.

The doubly labeled water technique has been validated in adults21 and infants,22 and is well suited to measure TEE in children, especially in children with disabilities, because all that is required is drinking a glass of labeled water and the collection of some urine samples.23 Using a fixed respiratory quotient for the calculation of energy expenditure for longer periods has been shown to produce minimal error (error in estimation is 1% for each 0.01 unit deviation).24

The TEE_{aw} measured in the healthy children is in good agreement with TEE_{aw} data of 7- and 9-year-old children living in Northern Ireland25 and in England.26 Most nutritional studies in children with CP are based on dietary intakes and often report low daily energy requirements (but with great interindividual variations).4,5,27-31 The results of our study, in which free-living energy expenditure was measured directly with doubly labeled water, confirm this low average daily energy requirement in young children with spastic CP. Per kilogram of FFM, differences between the children with CP and the healthy children were not statistically significant, in agreement with previous reports.4,31

The TEE/SMR ratio is an expression on the amount of energy expended above resting and represents the energy spent on activity and the thermic effect of food.32 Because there are no indications that diet-induced thermogenesis dif-
fers between children with CP and healthy children, differences in TEE/SMR ratios between the two groups are probably due to differences in levels of physical activity. The TEE/SMR ratio did not differ between the children with CP and the healthy children, indicating that levels of physical activity in a room-sized chamber are similar in children with CP and healthy children. The TEE/SMR ratio measured in our study is similar to ratios found in healthy adults during a stay in a respiration chamber.33 The TEE/SMR ratio in the healthy children was on average 25% greater than the TEE/SMR ratio, in agreement with results found in healthy adult men (age 25 to 61 years).33 In the children with CP, the TEE/SMR ratio did not differ from the TEE/SMR ratio. Apparently, children with spastic diplegia are, in contrast with healthy subjects, not more physically active under free-living conditions than in a room-sized chamber.

Bandini et al.6 reported a 30% lower TEE/SMR ratio in nonambulant adolescents with CP than in healthy control subjects, but no differences were found in the TEE/SMR ratio between ambulant adolescents with CP and their healthy peers. We found the lowest TEE/SMR ratio in the child using a wheelchair, but the TEE/SMR ratio of the ambulant children with CP was also significantly lower than in their healthy control subjects. This discrepancy between the findings of our study and those of Bandini et al. may be explained by the fact that levels of daily physical activity in healthy children gradually decrease with increasing age.34 Differences in physical activity between subjects with CP and healthy subjects may thus be smaller during adolescence than in childhood.

We conclude that, even at young ages, ambulant children with spastic diplegia are considerably less active than their healthy peers. Habitual activity patterns in these children, including physical education classes and physical therapy, are not sufficiently intense to achieve optimal levels of daily physical activity. It is to be expected that children with CP who are more severely affected than the children in this study, and who are not able to ambulate, will have even lower levels of daily physical activity. Besides detrimental effects on activities of daily living, the low levels of physical activity in children with CP may also reduce the effectiveness of rehabilitation programs, in which a great deal of surgical, physiotherapeutic, and educational effort is invested. We recommend increasing the daily physical activity of children with CP by special sports programs, adjusted to the residual ability of each child, to give opportunities for more normal growth and development.

We thank all the children and their parents who participated in this study and the children's rehabilitation center Franciscuszorg for their cooperation. We also thank Leuk Wouters and Paul Schoffelen for their help during data collection and analysis.

REFERENCES

ANNOUNCEMENT

Effective November 1, 1995, please send all manuscripts and other submissions for The Journal of Pediatrics to the Editor Designate:

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