Treadmill Training With Partial Body Weight Support in Nonambulatory Patients With Cerebral Palsy

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Objective: To examine the potential role of treadmill training with partial body weight support in nonambulatory children with cerebral palsy.

Study Design: Open, nonrandomized, baseline-treatment study.

Setting: An outpatient rehabilitation clinic.

Subjects: Ten children with cerebral palsy. Six children (group A) were nonambulatory, and four children (group B) either required continuous physical help (two cases) or were able to walk short distances with a stand-by or independently (one case each).

Intervention: Three months of additional treadmill training, three times a week, 2.5 minutes a session.

Main Outcome Measures: Functional Ambulation Categories, standing and walking section of the Gross Motor Function Measure, assessed at two baseline measurements 6 and 3 weeks before the study onset, at the beginning, and at the end of therapy.

Results: Measurements during baseline and at the study onset did not differ. During therapy, the mean Functional Ambulation Category improved significantly from 1.1 to 1.9 ($p < .05$). The sum score of the standing section of the Gross Motor Function Measure increased by 47% ($p < .05$). The walking section score increased by 50% ($p < .01$). Of the six nonambulatory children in group A, transfer abilities improved in four, one child could walk short distances independently, and two children could walk with continuous physical support after therapy. Of group B, one child could climb stairs independently, three children only needed verbal support while walking, and all subjects could then stand up arm-free after therapy.

Conclusions: Treadmill training with partial body weight support is a promising treatment technique in nonambulatory children with cerebral palsy.

Key Words: Children; Cerebral palsy; Gait; Treadmill training; Rehabilitation.

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CEREBRAL PALSY (CP) is a nonprogressive disorder of movement and posture caused by a defect or lesion of the immature brain. It occurs in approximately 2.5 of 1,000 births in the developed countries. The main motor function problems of children with CP are the delay or arrest of motor development. Children with CP either remain wheelchair-dependent or reach a low walking level characterized by slow speed and disturbed motor control, resulting in numerous disabilities and handicaps. In an effort to improve walking function in children with CP, therapists usually emphasize tone-inhibiting maneuvers, balance training, and gait-preparatory tasks during crawling, sitting, and standing.

Modern concepts of motor learning, however, favor a task-specific repetitive approach, i.e., "the one who wants to learn walking has to walk." The present preliminary study, therefore, examined the potential role of treadmill training with partial body weight support in one ambulatory and nine nonambulatory children with CP after a first feasibility study by Hesse and associates.

Treadmill training with partial body weight support has proved effective in restoring gait in adult paraparetic and hemiparetic subjects. Severely affected, nonambulatory patients could practice complex gait cycles repetitively. The patients were secured in a modified parachute harness to substitute for inefficient equilibrium reflexes and part of their body weight could be released to meet the requirements of their parietic lower limbs. The theoretical basis of the treatment concept was an activation of spinal and supraspinal pattern generators described in animal experiments. The resulting locomotor rhythms are innate in newborn children and can even be performed by anencephalic children. It, thus, seemed appropriate to transfer the theoretical concept of a possible activation of innate locomotor capabilities by treadmill training to the locomotor therapy of children with CP.

The present open study describes the treatment, the subjective impression of the children and their caregivers, and any improvement of their gait and motor ability during a training period of 3 months. Dependent variables were the Functional Ambulation Categories (FAC) and the standing and walking section of the Gross Motor (GM) Function Measure. Both scores have been applied as valid and reliable assessment instruments in previous studies on treadmill training in hemiparetic subjects and other treatment modalities such as horse riding or rhizotomy in combination with physiotherapy in children with CP.

MATERIAL AND METHODS

Subjects

Ten children with CP participated in the open study approved by the local ethical committee after parents' written consent. They were four boys and six girls. Their mean age was 11.5 years, with a range from 6 to 18 years. Three subjects suffered from spastic diplegia, four subjects from spastic tetraparesis, and three subjects from spastic tetraparesis with additional ataxia. The etiology was perinatal hypoxia in eight cases and was unknown in two subjects.
The children met the following inclusion criteria: (1) ability to stand holding on with both arms for at least 3 seconds, (2) no fixed contractures of the lower limb joints, (3) no other orthopedic or neurological diseases impairing mobility, (4) no previous operations (e.g., tendon transfer or lengthening) or neurolytic treatment 6 months before study onset, and (5) no severe cognitive or communicative impairment, i.e., all children could follow instructions.

The children could be classified into two groups on the basis of their walking ability (table 1). Six children (group A), all of them tetraparetic, could not walk at all or required very firm support during intended ambulation (FAC 0); for daily mobility they used a wheelchair actively (two cases) or were pushed by caregivers (four cases). Four children (group B) were able to walk to a varying extent: two children needed continuous or intermittent support for balance and/or coordination by one therapist (FAC 2), one child required verbal supervision or standby help by one therapist (FAC 3), and one child could walk independently in an athetoid manner on level ground (FAC 4). Crutches and orthopaedic shoes were used by all children of group B while walking. Nine children’s usual means of mobility was by self-propelling in a wheelchair.

Treadmill Training

Locomotion therapy was performed on a motor-driven treadmill with variable speed control. Patients were supported in a modified parachute harness suspended vertically via ropes and pulleys connected to an adjustable counterweight of 2 kg increments (fig 1). The system provided a present degree of body weight support (BWS), which was kept almost constant throughout the gait cycle. Its mean value at the beginning of therapy was 14.0% of body weight (BW) with a range from 0% to 40%. The harness allowed free movement of the arms and trunk but did not need body weight support. The children could hold on to height-adjustable lateral rails to provide additional balance but not body weight support.

At the beginning of the treadmill training, two neurodevelopmental techniques (NDT)–trained therapists were necessary to provide manual help to assist the movement of both lower limbs. Sitting at the side of the treadmill, they facilitated the swing of the paretic limbs, paid attention that the initial contact was made with the heel, prevented knee hyperextension during midstance, and prolonged the stance phase by preventing premature initiation of the swing phase of both lower limbs. The prolongation of the stance phase in combination with the backward movement of the belt resulted in an increased hip extension. The children were not allowed to sit in the harness. This was most likely when hip extension was incomplete or when the speed of the belt was too fast. Then the patients tended to compensate for the higher velocity by faster and shorter steps, but were unable to carry their own weight. Treadmill speed was adjusted to a comfortable cadence and stride length of each patient. The amount of body weight support was set according to clinical criteria in such a way that the children were able to carry their body weight sufficiently during the single-stance phase of each lower limb without knee collapse of excessive hip flexion. During training, the support was reduced as soon as possible according to the previously mentioned clinical criteria.

Mean treadmill speed was .23 m/sec (range, .14–.42) at the beginning of the training. It increased continuously to a mean of .34 m/sec (range, .25–.47) at the end of therapy. The mean net walking time was 12.8 minutes (range, 10.0–19.2) at the beginning of treatment. It increased continuously in 8 subjects and remained rather constant in 2 patients who experienced marked fatigue. The mean value was 18.8 minutes (range, 12.3–25.0) at the end of treatment. Correspondingly, the walking distance covered during one treadmill session increased by approximately 50% over all subjects. Five subjects of group A required a body weight support of 20% (2 cases), 30% (2 cases), and 40% (1 case) of body weight at the beginning of the training, which was then gradually reduced. The remaining five subjects took advantage of the harness-related stabilization of the trunk but did not need body weight support.

Experimental Protocol

All children were outpatients. The study lasted 3 months, during which time the children received three treadmill sessions per week, totalling 36 sessions. Each session lasted 30 minutes.

Table 1: Clinical Data and Functional Assessment Scores of Each Subject

<table>
<thead>
<tr>
<th>Age/Sex</th>
<th>Diagnosis</th>
<th>BWS (%)</th>
<th>FAC* (0-5)</th>
<th>GM Function Measurement, Standing Section (0-42)</th>
<th>GM Function Measurement, Walking Section (0-45)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>b1-b2-start-3mo</td>
<td>b1-b2-start-3mo</td>
<td>b1-b2-start-3mo</td>
</tr>
<tr>
<td>Group A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/F</td>
<td>Spastic tetraparesis</td>
<td>40</td>
<td>0-0-0-0</td>
<td>3-3-3-3</td>
<td>5-6-5-11</td>
</tr>
<tr>
<td>8/F</td>
<td>Spastic tetraparesis</td>
<td>20</td>
<td>0-0-0-0</td>
<td>5-4-5-12</td>
<td>2-3-3-9</td>
</tr>
<tr>
<td>10/M</td>
<td>Spastic tetraparesis</td>
<td>20</td>
<td>0-0-0-0</td>
<td>8-8-8-8</td>
<td>4-6-5-9</td>
</tr>
<tr>
<td>15/F</td>
<td>Spastic tetraparesis</td>
<td>30</td>
<td>0-0-0-0</td>
<td>12-10-11-25</td>
<td>9-8-9-15</td>
</tr>
<tr>
<td>18/M</td>
<td>Spastic tetraparesis</td>
<td>0</td>
<td>0-0-0-0</td>
<td>4-4-4-6</td>
<td>2-3-3-3</td>
</tr>
<tr>
<td>7/F</td>
<td>Spastic tetraparesis</td>
<td>30</td>
<td>0-0-0-0</td>
<td>6-2-5-8-6-0-10.8</td>
<td>4.8-5.2-5.2-2.8-5</td>
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<td>Mean age</td>
<td>11.1</td>
<td>23.3</td>
<td>0-0-0-0.83</td>
<td>17.8-17.8-18.3-23.5</td>
<td>16.3-16.0-17.5-22.5</td>
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<tr>
<td>Group B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8/M</td>
<td>Spastic diparesis</td>
<td>0</td>
<td>2-2-2-3</td>
<td>8-8-8-8</td>
<td>5-5-5-9</td>
</tr>
<tr>
<td>18/F</td>
<td>Spastic tetraparesis</td>
<td>0</td>
<td>4-4-4-5</td>
<td>36-35-36-39</td>
<td>30-28-32-42</td>
</tr>
<tr>
<td>12/M</td>
<td>Spastic diparesis</td>
<td>0</td>
<td>3-3-3-3</td>
<td>19-21-21-21</td>
<td>18-19-18-21</td>
</tr>
<tr>
<td>9/F</td>
<td>Spastic diparesis</td>
<td>0</td>
<td>2-2-2-3</td>
<td>8-7-8-20</td>
<td>12-12-12-12</td>
</tr>
<tr>
<td>Mean age</td>
<td>11.7</td>
<td>0</td>
<td>2.75-2.75-2.75-3.50</td>
<td>17.8-17.8-18.3-23.5</td>
<td>16.3-16.0-17.5-22.5</td>
</tr>
</tbody>
</table>

Abbreviations: b1, baseline measurement 6 and 3 weeks before study onset; start, study onset; 3 mos, after 3 months of treadmill training; BWS%, amount of body weight support in % body weight at the beginning of therapy; 0% means that the patients wore the harness but no body weight support was required.

* Group A: initial FAC 0; group B: initial FAC >2.
including 5 minutes of donning and doffing. Within the possible 25 minutes of net-training time, subjects were encouraged to walk continuously on the treadmill for at least 5 minutes before breaking. The maximum duration of one block was 10 minutes followed by a compulsory break according to individual needs. All subjects wore their custom-made orthopedic shoes, and additional braces or splints were not required. Patients were habituated to treadmill training in three 20 minutes sessions before the study onset. Physiotherapy continued at a level of two to three 30-minute treatment sessions per week during the study. Further, any medication was kept constant.

Assessment

The children were rated at 0 and 3 weeks before the study onset, and at the beginning and end of treadmill training. Assessment included the FAC (0 through 5), and the standing and walking sections of the GM Function Measurement.

FAC level was chosen to document gait ability. The test includes six levels of personal support needed for gait but does not note whether an aid was used. Level 0 describes a patient who can not walk or requires the help of two or more people. Level 1 describes a patient who needs continuous support from one person with carrying weight and balance, and level 2 describes a patient who is dependent on continuous or intermittent support of one person to help with balance or coordination. Level 3 describes a patient who needs only verbal supervision, a level 4 patient requires help on stairs and uneven surfaces, and level 5 describes a patient who can walk independently anywhere. It was tested on a 20-meter walkway.

Within the standing section of the GM Function Measure, 13 maneuvers are tested such as standing with both or one hand holding on, arm free, lifting one foot while standing, sit-to-stand transfer, high kneeling, and picking up an object from the sitting or standing position. Four performance levels (0 through 3) are further distinguished for each of the 13 items, where 0 means that the task could not even be initiated, and levels 1 to 3 describe different performance abilities within the item.

Within the walking section of the GM Function Measure, 14 maneuvers are tested such as walking with hands led on, without arm support, in different directions, stepping over obstacles, climbing and ascending stairs, walking on a straight line, kicking a ball, running, and jumping. Again, four levels of performance (0 through 3) are further distinguished for each of the 13 items (see previous section). The sum for each section could range from minimal 0 to maximal 39 (equals 3 × 13) points for standing and 0 to 42 (equals 3 × 14) points for walking. Two independent and experienced raters (one physiatrist and one physiotherapist) performed the assessments, they were not involved in the therapy, and were blind with respect to each patient's stage within the study. The intrater reliability was larger than 0.9 for the FAC, and .81 and .83 for the two GM Function Measure sections.

Children and caregivers were asked for their overall impression about the therapy, with particular emphasis on any improvement of their daily mobility, satisfaction or joy related to the training, and whether they could recommend it.

Statistical Analysis

Dependent variables were the FAC, and the standing and walking sections of the GM Function Measure. Any difference before and after the 3-month training period were tested by the nonparametric Wilcoxon test (p < .05).

RESULTS

Subjective Impression

Four children (and their caregivers) in group A found the training motivating and joyful because they could practice gait to a much larger extent compared with a conventional physiotherapy session. They noted an improvement of their motor abilities to some extent and unreservedly recommended the training. One subject reported that he no longer used his wheelchair at home, whereas the remaining three subjects remained wheelchair-dependent but reported some improvements of motor functions such as wheelchair transfer, standing, and/or sit-to-stand maneuver during their daily activities. The two remaining subjects of group A found the training rather exhausting and noted no relevant difference of their motor functions afterward.

All four subjects of group B found the training motivating and joyful and could fully recommend it. Among them, one subject who was ambulatory in an athetoid manner before training (initial FAC score of 4) reported that after therapy she was able to climb one floor. Furthermore, she reported that she had learned a "new" and more controlled walking pattern. Caregivers and physiotherapists agreed and noticed less athetoid movements and a better trunk control. The remaining three subjects all noticed some improvement of their motor abilities (eg, transfer, sit-to-stand maneuver), but were still dependent on a wheelchair during their routine daily activities. No children or caregivers reported side effects of treatment.
Functional Ambulation Category

The two baseline measurements of the FAC of all children did not differ from the measurement at the study onset. The baseline scores and the score at the study onset of the standing and walking sections of the GM function showed that the levels of performance within items oscillated inconsistently in six subjects for a maximum of two points. None of the children, however, differed with respect to the overall number of items performed on the three consecutive measurements.

FAC grade increased from a mean of 1.1 to 1.9 after the treatment (fig 2; \( p < .05 \)). The previously mentioned two subject groups behaved as follows: of the six subjects of group A, one child experienced a 3-level improvement (ie, he could walk independently with verbal supervision at the end of training). Two children improved for one level and three children did not show any improvements of the FAC scores.

In group B, the two children with an initial FAC score of 2 improved for 1 level (ie, they became independent walkers still requiring verbal supervision and/or standby). Of the remaining two subjects, one child was then able to climb stairs without physical support and to walk independently on any surfaces.

Gross Motor Function Measurement

The standing score from the GM Function Measure increased from a mean of 10.9 to 15.9 after the treatment (fig 3; \( p < .05 \)). Four children of group A exhibited an improvement of their standing ability, being able to lift one foot while standing (in two cases, this was not possible before therapy) and to perform the sit-to-stand transfer independently (two cases needed help before) after therapy. One subject gained two new items: first, the ability to lift off each foot separately while standing arm free, and second, the ability to stand up from a bench without using arms (this child was able to do this before only with the help of his arms).

All subjects of group B improved their postural abilities during therapy being then able to stand up from a sitting position arm free (three cases, two children were not able to perform the movement at all and one child used his arms before therapy). One child was newly able to lift one foot while standing arm free, and one subject was able to sit down, to attain a squat, and to pick up an object from the floor with arms free (she had used her arms for these tasks before therapy).

The walking score from the GM Function Measure increased from a mean of 9.8 to 14.1 after the treatment (fig 4; \( p < .01 \)). Five children of group A showed an improvement of their individual scores. They were able to cruise five steps instead of one to the right and to the left while standing and holding a bench (four cases). One subject whose FAC level improved from 0 to 3 correspondingly gained two items of this section, namely walking 10 steps forward with one hand held and even without physical support.

All subjects of group B improved their scores. They were newly able to walk backward 3 to 10 steps (three cases), to walk forward 10 steps, stop and return (in two cases this was not possible before therapy). The athetoid subject mentioned earlier gained five new items: walking on a line, jumping forward 2 inches, hopping on one foot less than three times, stair climbing while holding on to one rail, and descending stairs in an alternate fashion.

DISCUSSION

The major finding of the preliminary study was that 3 months of treadmill training with partial body weight support was associated with a clinically relevant improvement of walking in six and other motor abilities in 8 of the 10 children with CP. This result was confirmed both by the subjective impression of the children and their caregivers and the chosen assessment instruments.

All eight children who had sufficient stamina to increase the walking distance on the treadmill benefited, but the other two who found the treatment exhausting did not improve.

Four children (group B) had varying locomotor capabilities before training. They profited from the therapy as follows: one child, ambulatory on ground level before treatment, could then climb stairs independently; and the remaining three children (active wheelchair users) only needed verbal support while walking forward, and even backward. Further, all four children could stand up arm free after therapy, whereas they had to use their arms before the onset of training.

These observed positive results may be ascribed to the
TREADMILL TRAINING IN CHILDREN WITH CP, Schindl

Fig 3. Mean (± standard deviation) scores of the standing section (0-39) of the GM function measurement 6 and 3 weeks before the study onset, at the study onset, and after 3 months of treadmill training (p = .018).

The improvements in walking ability seem to favor the concept of a repetitive task-specific approach also in children with CP who are learning walking. Complex gait cycles were exclusively used during treadmill training, whereas other treatment concepts tend to have a broader approach that includes the use of gait-preparatory and tone-inhibiting maneuvers or reflex patterns, as well as the repetitive practice of various motor tasks. Nevertheless, treadmill training also resulted in an improvement of functions other than gait (eg, standing, transfer, rising). Besides an unspecified training effect, one might assume a transfer of therapeutic effects from gait to other mobility related motor tasks practiced mainly during the ongoing conventional physiotherapy. The corresponding mean changes of the standing (+47.2%) and walking section (+50.0%) are comparable to or above the reported values in the literature on 8-week hippotherapy,16 and dorsal rhizotomy alone and in combination with physiotherapy for 6, 9, and 12 months.17,19

The improvements in walking ability of the diparetic and tetraparetic children with CP are partly in keeping with previous reports on chronic paraparetic and tetraparetic subjects after spinal cord injury, although the site and extent of neurologic...
lesions in both patients is different. Wernig and associates,²⁰ for instance, reported that 20 of 25 wheelchair-dependent (spinal cord injury) chronic paraparetic subjects regained and maintained a limited walking ability after an intensive training period from 3 up to 9 months. Based on animal experiments showing the restoration of gait in adult spinalized cats by treadmill training with partial body weight support,¹¹ the authors presumed an activation of spinal and supraspinal pattern generators pattern. This notion was confirmed by subsequent neurophysiologic studies showing locomotor-like rhythmic electromyographic activity of lower limb muscles even in paraplegic subjects during treadmill training with partial body weight support.²⁰,²¹

Also, the restoration of gait in both stroke and paraparetic subjects was not accompanied by an increase of muscle strength, suggesting that treadmill therapy was more than a sheer muscle training but also acted on a neuronal level.⁸,¹⁰

Further evidence are rhythmic locomotor activities of newborn children, which can even be performed by anencephalic children. Accordingly, it seems appropriate to favor the concept of an activation of existing spinal and supraspinal pattern generators in children with CP as relevant for the effect of treadmill training. Pure muscle paresis, on the other hand, seemed to play a minor role because the children required very little support as compared with spinal cord injury and stroke subjects. The harness was mostly required to compensate for deficient equilibrium reflexes during the therapy.

Children with CP of this study (except one child) had never been walking independently before the treatment, whereas spinal cord injury patients had been healthy ambulators in most cases before the accident. This difference in walking experience might explain the higher ratio of independent ambulators in the previously mentioned study of Wernig and associates²⁰ on paraparetic subjects, as compared with the present study.

Spasticity and movement disorders were not particularly addressed in this study. One subject, ambulatory before the treatment, reported that she had learned to walk in a less atetrodol and less spastic manner and that she could switch between her old and new walking pattern. In stroke subjects, it is known that hemiparetic patients walk more symmetric and less spastic on the treadmill as compared with floor walking,²² which might also apply to children with CP. Furthermore, the harness may have constrained abrupt trunk and shoulder movements, rendering the subject's gait more controlled.

In conclusion, this preliminary open study shows the potential of treadmill training in children with CP. The initially tiresome training was well tolerated and resulted in a relevant improvement of walking and other motor abilities in 8 of 10 children. The results justify further studies to evaluate this promising technique in children with CP.

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References