The purpose of this study was to evaluate effects of a progressive strength training programme on walking ability in adults with cerebral palsy. Ten individuals with spastic diplegia (seven males, three females; mean age 31, range 23–44 years) participated twice a week over 10 weeks. Seven individuals with spastic diplegia (four males, three females; mean age 33, range 25–47 years) who did not receive strength training served as controls. All individuals were ambulatory but motor ability ranged from functional walkers to individuals who always required walking aids and used a wheelchair regularly. Significant improvements were seen in isometric strength (hip extensors \( p=0.006 \), hip abductors \( p=0.01 \)), and in isokinetic concentric work at 30˚/s (knee extensors \( p=0.02 \)) but not in eccentric work. Results also showed significant improvements in Gross Motor Function Measure (GMFM) dimensions D and E \( (p=0.005) \), walking velocity \( (p=0.005) \), and Timed Up and Go \( (p=0.01) \). There was no increase in spasticity for those who underwent strength training. Individuals in the control group did not show any significant improvement in any measured variable. The groups were small, however, and there was no significant difference between the groups in any measured variable. These findings suggest that a 10-week progressive strength training programme improves muscle strength and walking ability without increasing spasticity.

Cerebral palsy (CP) is a general term used to describe a wide variety of motor disorders. Increased latency of onset of movement, poor temporal and spatial organization of muscles and joints, inadequate muscle force production, hypertonus, and agonist/antagonist co-contraction characterize spastic CP (Campbell 1991). Spastic diplegia is the most common form of CP (Watt et al. 1989) and it is characterized by greater involvement in the lower extremities than in the upper extremities (Bax 1964). The imbalance of muscle strength and tone causes muscle weakness and atrophy over time, as well as soft tissue contracture and eventual joint deformity (Damiano et al. 1995a).

Physiotherapy has been directed at inhibiting spasticity, with the expectation that this inhibition would allow more normal sensorimotor experiences and result in more normal movement patterns. Until recently muscle weakness had not been recognized as a problem in individuals with CP. Interventions like orthopaedic surgery, selective dorsal rhizotomy, and injections with botulinum toxin-A are now frequently used. These methods aim to improve muscle length and to reduce spasticity and thereby improve motor function. It has become clinically evident that reduced spasticity has revealed underlying muscle weakness and abnormal movement patterns in many children (Guiliani 1991, Bleck 1994, Thompson 1994) and, therefore, training of muscle strength and coordination has been recommended to improve motor function. Bobath (1971) considered spasticity to be the main problem in spastic CP and suggested that resistance training should be avoided because it could lead to increased spasticity and associated reactions. However Carr et al. (1995) stated that it is not the presence of spasticity but the negative features of weakness and loss of skill which are the major barriers to improved function. Many studies have reported positive results in strength training in children with spasticity (Kramer and MacPhail 1994; Damiano et al. 1995a,b; MacPhail and Kramer 1995) and in stroke patients (Engardt et al. 1995, Sharpe and Brouwer 1997, Teixeira-Salmela et al. 1999, Weiss et al. 2000). Kramer and MacPhail (1994) reported a significant relation between knee-extensor strength and both walking efficiency and gross motor ability in adolescents with CP while Damiano and Abel (1998) reinforced the theory of the relationship between strength and motor function in a strength training study in children with CP.

Horvat (1987) reported a case study regarding strength training in adults with CP. A 21-year-old male with CP (spastic hemiplegia) followed a strength training programme during eight weeks, three times per week, and showed improvements in strength, endurance, and range of motion on both sides of the body.

No report on other types of training in adults with CP has been found, although some have reported health problems and continuing impairment and disability (Cathels and Reddihough 1993, Murphy et al. 1995, Turk et al. 1997). Andersson and Mattsson (2001) found that 79% (61 of 77) of adults with spastic diplegia were able to walk with or without walking aids but 51% (31 of 61) of those claimed that their walking ability had decreased during recent years, and 9% reported that they had stopped walking. The reasons reported by the patients for the decreased walking ability included deterioration of condition, muscle strength, and balance control.

Our experience is that individuals with CP usually stop training after having reached adulthood. They are often tired of physiotherapy after having undergone it all their lives.
When they find that motor capacity has deteriorated they may want to start training again. Whether it is possible to increase or restore motor capacity is not clear. We think that it is important to answer this question as it will be of great importance to adolescents as well as children with CP. Strength training is a very popular form of training among both adults with and without disabilities but until recently it has not been recommended for individuals with CP. Our clinical experience is that adults with CP often ask for training that is effective and also easily available in society.

The purpose of this study was to evaluate whether a progressive strength training programme would affect spasticity, range of motion and muscle strength, and consequently improve walking ability in adults with CP.

**Method**

**PARTICIPANTS**

The criteria for participation were that the individual (1) had diagnosed spastic CP; (2) was able to walk, with or without walking aids; (3) had reported decreased walking ability during recent years; (4) had not participated in strength training during the last year.

Participants were selected from a previous study of Swedish adults with CP (Andersson and Mattsson 2001). They had answered a questionnaire and also stated that they thought training would improve their walking ability. Forty individuals (31 with spastic diplegia and nine with spastic hemiplegia) fulfilled the criteria.

Twenty-two individuals declined to participate in the study, mostly because of lack of time. They were working, studying, or had other plans for their rehabilitation. Eighteen individuals with spastic diplegia agreed to participate in the study and were selected into either a training group or a control group, depending on their availability for training. One male in the control group was excluded from the study because he started strength training during the control period. The training group consisted of 10 participants (seven males, three females; mean age was 31 (23–44) years. The control group consisted of seven participants (four males, three females); mean age was 33 (25–47) years. The control group was offered a training period after the control period. All participants were ambulatory but motor ability ranged from functional walkers (five in the training group and four in the control group) to individuals who always required walking aids and used a wheelchair regularly. Individual data are presented in Table I. Training took place in an ordinary gym with strength training equipment. All participants were instructed not to alter their everyday physical activities during participation in this study.

The study was approved by the Ethic Committee at Huddinge University Hospital, Huddinge, Sweden and all participants gave informed consent.

**MEASUREMENTS**

Spasticity, range of movement, isometric and isokinetic muscle strength, gross motor function, and six-minute walking tests were performed at the beginning of the training period and after ten weeks and were performed by two physiotherapists who were not involved in the training procedure.

**Spasticity**

Spasticity was estimated in a supine relaxed position according to the modified Ashworth scale (Bohannon and Smith 1987). The modified Ashworth scale has six degrees (0, 1, 1+, 2, 3, 4) and the movements tested included hip abduction/adduction, hip flexion/extension, knee flexion/extension, and ankle flexion/extension. Participants also gave subjective impressions of the spasticity after each training session. Interrater reliability of 

| Table I: Sex, age, diagnosis, spasticity on right and left side, use of walking aids, and use of wheelchairs. Training group (n=10) and control group (n=7) |
|-----------------|-----------------|------------------|-----------------|-----------------|-----------------|-----------------|
| **Group** | **Sex** | **Age (y)** | **Diagnosis** | **Spasticity (0–4)** | **Walking aids** | **Wheelchair** |
| | | | | **Right** | **Left** | | |
| **Training** | | | | | | |
| 1 | M | 41 | Spastic diplegia | 1+ | 2 | Crutches (outside) | Sometimes |
| 2 | M | 44 | Spastic diplegia | 1+ | 2 | Rollator | Electric WC (often) |
| 3 | M | 34 | Spastic diplegia | 2 | 2 | No | Sometimes |
| 4 | M | 32 | Spastic diplegia | 1+ | 1+ | No | Sometimes |
| 5 | F | 28 | Spastic diplegia (and athetosis) | 2 | 2 | Rollator | Often |
| 6 | M | 30 | Spastic diplegia (and athetosis) | 1+ | 1+ | No | Often |
| 7 | F | 27 | Spastic diplegia | 1+ | 1+ | No | Sometimes |
| 8 | M | 24 | Spastic diplegia | 2 | 2 | Crutches | Often |
| 9 | F | 23 | Spastic diplegia | 2 | 2 | Crutches | Often |
| 10 | M | 23 | Spastic diplegia | 1+ | 2 | No | Sometimes |
| **Control** | | | | | | |
| 11 | F | 37 | Spastic diplegia | 2 | 2 | Rollator/crutches | Often |
| 12 | M | 25 | Spastic diplegia | 2 | 2 | Rollator/crutches | Often |
| 13 | M | 47 | Spastic diplegia | 1 | 1 | No | No |
| 14 | M | 41 | Spastic diplegia | 2 | 1+ | Crutches | Sometimes |
| 15 | F | 29 | Spastic diplegia | 1+ | 2 | Crutches | Often |
| 16 | F | 25 | Spastic diplegia | 1+ | 1+ | No | No |
| 17 | M | 25 | Spastic diplegia | 1 | 1+ | No | Sometimes |

*a According to the modified Ashworth scale (Bohannon and Smith 1987).*
### Table IV: Isokinetic strength at 90˚/s in right and left knee extensors before and after 10 weeks. Training group (n=10) and control group (n=7)

<table>
<thead>
<tr>
<th>Type of test</th>
<th>Before Right</th>
<th>After Right</th>
<th>p</th>
<th>Before Left</th>
<th>After Left</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Training group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric work (J) median</td>
<td>16</td>
<td>18</td>
<td>ns</td>
<td>15</td>
<td>20</td>
<td>0.05</td>
</tr>
<tr>
<td>Range</td>
<td>3–52</td>
<td>7–65</td>
<td></td>
<td>5–53</td>
<td>7–46</td>
<td></td>
</tr>
<tr>
<td>Eccentric work (J) median</td>
<td>50</td>
<td>58</td>
<td>0.03</td>
<td>53</td>
<td>58</td>
<td>ns</td>
</tr>
<tr>
<td>Range</td>
<td>14–72</td>
<td>18–81</td>
<td></td>
<td>19–71</td>
<td>18–64</td>
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</tr>
<tr>
<td>Concentric peak torque (Nm) median</td>
<td>15–109</td>
<td>28–129</td>
<td></td>
<td>21–113</td>
<td>27–110</td>
<td></td>
</tr>
<tr>
<td><strong>Control group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric work (J) median</td>
<td>12</td>
<td>15</td>
<td>ns</td>
<td>10</td>
<td>11</td>
<td>ns</td>
</tr>
<tr>
<td>Range</td>
<td>2–93</td>
<td>5–127</td>
<td></td>
<td>5–108</td>
<td>7–102</td>
<td></td>
</tr>
<tr>
<td>Eccentric work (J) median</td>
<td>47</td>
<td>53</td>
<td>ns</td>
<td>33</td>
<td>41</td>
<td>ns</td>
</tr>
<tr>
<td>Range</td>
<td>12–156</td>
<td>11–196</td>
<td></td>
<td>7–108</td>
<td>15–158</td>
<td></td>
</tr>
<tr>
<td>Concentric peak torque (Nm) median</td>
<td>34</td>
<td>37</td>
<td>ns</td>
<td>35</td>
<td>48</td>
<td>ns</td>
</tr>
</tbody>
</table>

*ns*, non significant; J, joule; Nm, Newton metre; ns, non significant.

### Table III: Isokinetic strength at 30˚/s in right and left knee extensors before and after 10 weeks. Training group (n=10) and control group (n=7)

<table>
<thead>
<tr>
<th>Type of test</th>
<th>Before Right</th>
<th>After Right</th>
<th>p</th>
<th>Before Left</th>
<th>After Left</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Training group</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric work (J) median</td>
<td>18</td>
<td>23</td>
<td>0.01</td>
<td>17</td>
<td>25</td>
<td>0.02</td>
</tr>
<tr>
<td>Range</td>
<td>3–59</td>
<td>8–71</td>
<td></td>
<td>6–57</td>
<td>9–55</td>
<td></td>
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<tr>
<td>Eccentric work (J) median</td>
<td>30</td>
<td>30</td>
<td>ns</td>
<td>32</td>
<td>30</td>
<td>ns</td>
</tr>
<tr>
<td>Range</td>
<td>11–74</td>
<td>17–80</td>
<td></td>
<td>17–65</td>
<td>18–72</td>
<td></td>
</tr>
<tr>
<td>Concentric peak torque (Nm) median</td>
<td>57</td>
<td>69</td>
<td>0.03</td>
<td>59</td>
<td>67</td>
<td>ns</td>
</tr>
<tr>
<td>Range</td>
<td>16–125</td>
<td>35–149</td>
<td></td>
<td>25–121</td>
<td>33–129</td>
<td></td>
</tr>
<tr>
<td><strong>Control group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric work (J) median</td>
<td>14</td>
<td>17</td>
<td>ns</td>
<td>12</td>
<td>12</td>
<td>ns</td>
</tr>
<tr>
<td>Range</td>
<td>3–103</td>
<td>6–142</td>
<td></td>
<td>6–120</td>
<td>8–115</td>
<td></td>
</tr>
<tr>
<td>Eccentric work (J) median</td>
<td>54</td>
<td>59</td>
<td>ns</td>
<td>59</td>
<td>42</td>
<td>ns</td>
</tr>
<tr>
<td>Concentric peak torque (Nm) median</td>
<td>42</td>
<td>45</td>
<td>ns</td>
<td>44</td>
<td>55</td>
<td>ns</td>
</tr>
</tbody>
</table>

*J*, joule; Nm, Newton metre; *ns*, non significant.
the modified Ashworth scale has been considered good ($r=0.85$; Bohannon and Smith 1987).

**Range of motion**
Passive range of motion in flexion/extension were measured at the hip and knee using a goniometer (Rothstein et al. 1983). The participant was tested in a supine relaxed position.

**Isometric muscle strength**
A hand-held dynamometer (Model 01160, Nicholas MMT, Lafayette Instruments, Indiana, USA) was used to measure the maximum voluntary contraction in hip extensors and hip abductors bilaterally. The hand-held dynamometer has been shown to have a good interrater reliability (Bohannon and Andrews 1987) and is a reliable assessment technique when practised by a single experienced tester (Bohannon 1986). The standard test position was the lateral position with the lower leg in a flexed position. Before testing, the physiotherapist instructed the participant to practise the muscle contractions. Three maximal effort trials for each muscle group and leg were performed with 30 seconds' rest between each trial (Bohannon 1986). The best value of each muscle group and leg was chosen. When testing hip extension the upper leg was placed in the middle of the participant's total range of movement in the sagittal plane. The dynamometer was placed 10cm proximal to the lateral femur condyle and on

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**Figure 1: Training programme. With permission of Physio Tool, Ltd, Malmö, Sweden.**

1. Cycling
   5 minutes

2. Knee extensions
   3 x 10

3. Hip extensions
   3 x 10

4. Pull-downs
   3 x 10

5. Dips
   3 x 10

6. Leg press
   3 x 10

7. Heel rises
   3 x 15

8. Hip abductions
   2 x 15 (each leg)

9. Sit-ups
   2 x 20
   (some of participants needed manual leg support)

10. Diagonal lift (arm and leg)
    2 x 20

11. Stretching
    Hip muscles: iliopsoas, abductors, and adductors.
    Knee muscles: hamstrings, quadriceps.
    Foot muscles: triceps surae.
the dorsal part of the thigh. When testing hip abduction the upper leg was placed in as much extension as possible. The dynamometer was placed 10cm proximal to the lateral femur condyle on the lateral part of the leg. During the tests the same physiotherapist performed the measurements while the other physiotherapist helped to stabilize the thorax and the opposite hip. Absolute strength values in kg were recorded and used for further analyses.

**Isokinetic muscle strength**

Concentric and eccentric work (joules, J) and concentric peak torque (Newton metres, Nm) in quadriceps muscles were measured bilaterally by an isokinetic dynamometer (KIN-KOM 500H dynamometer, Chattecx Corp., Chattanooga, USA) at two different angle speeds (30˚/s, 90˚/s). Participants were positioned sitting with their backs against a backrest with their hips in 90˚ flexion. Their arms were crossed over the chest and pelvis and thighs were secured with straps. The resistance pad of the dynamometer was positioned over the distal part of the lower leg and secured with a strap. One maximal and at least three submaximal contractions preceded the actual test in order to familiarize the participant with the movement (MacPhail and Kramer 1995). Three maximal efforts were then performed, with 10 seconds’ rest between concentric and eccentric work and at least 20 seconds’ rest between each trial. Each participant started at an angular velocity of 30˚/s and verbal encouragement to perform at maximal effort was given.

Peak torque, concentric and eccentric work were noted. Peak torque was defined as the maximal torque (Nm) generated by the participant during a concentric movement. Work (J) was defined as the product of force acting through a distance during a concentric or an eccentric movement (Olney et al. 1990). The isokinetic strength test in individuals with CP has been shown to be reliable both at 30˚/s (van den Berg-Emons et al. 1996) and at 90˚/s (Ayalon et al. 2000).

**Gross Motor Function Measure (GMFM)**

The GMFM test is a validated instrument with good intra- and interrater reliability designed to assess motor status in CP and to quantify changes over time or as a result of intervention (Russell et al. 1989, Nordmark et al. 1997). It consists of 88 items within five dimensions: (A) lying and rolling; (B) sitting (C) crawling and kneeling; (D) standing; (E) walking, running, and jumping. Items are scored using a four-point Lickert scale (0, could not initiate task; 1, initiated task (<10% of task); 2, partially completed task (10 to <100%); 3, completed task). Scores are presented as percentages. Separate scores can be calculated for each of the five dimensions as well as for the total score. In this study only dimensions D and E were assessed, as our main objective was to evaluate motor function in walking after the intervention.

**Six-Minute Walking test**

Cooper (1968) developed the original 12-minute walking test for assessing maximal oxygen uptake in athletes. It was
modified by McGavin et al. (1976) for tests of individuals with disabilities and pulmonary diseases. The timing of the test was later altered by Butland et al. (1982) and has also been used in assessing exercise capacity in individuals with chronic heart failure (Lipkin et al. 1986).

Participants were asked to walk at a self-selected comfortable velocity and to use a walking aid if necessary. The testing area included a level floor and participants walked in a circle of 43 metres. Each participant was instructed to cover as much ground as possible in six minutes. The participant was allowed to rest if necessary during the walking session. Walking distance was noted and walking velocity was calculated. Perceived exertion was graded immediately after six minutes using the Borg scale (Rating of Perceived Exertion 6-20; Borg 1982) for perceived exertion.

Timed Up and Go (TUG)
TUG is a quick and practical method of testing balance in basic mobility manoeuvres (Podsiadlo and Richardson 1991). The test is based on a functional task of rising from a standard armchair, walking 3 metres, turning, and returning to the chair. Time in seconds required to complete the task was recorded. TUG is a sensitive and specific measure for identifying individuals who are at risk for falls (Shumway-Cook et al. 2000) and test–retest reliability and interrater reliability is good (ICC=0.99; Podsiadlo and Richardson 1991).

TRAINING PROCEDURE
The training took place for one hour twice a week for 10 weeks. Two physiotherapists supervised the group. The progressive strength training programme consisted of 10 exercises with emphasis on the lower extremities (Fig. 1). The training programme was followed by stretching (adductors, hamstrings, iliopsoas, quadriceps, and gastrocnemius) for 15 minutes.

In order to determine the appropriate load before starting strength training each position in the muscle training equipment was standardized according to the manufacturer’s instructions. One RM (one repetition maximum, i.e. the maximum weight the participant could lift in one repetition) was then identified in each participant and the weight was decided to be approximately 70% of 1RM. The participant then performed 10 repetitions in three sets with the calculated weight. When the participant managed to do more than 10 repetitions per set, the weight or resistance was increased. Each participant noted the weights in a protocol after each set of repetitions.

STATISTICS
Wilcoxon’s signed rank test was used to analyze differences over time and Mann–Whitney U test to analyze differences between the two groups. Spearman’s rank correlation test was used to determine correlation between variables. The correlations were interpreted according to guidelines adapted from Altman (1991) where $r<0.20$, poor; 0.21–0.40, fair; 0.41–0.60, good; 0.61–0.80, very good; 0.81–1.0, excellent.

<table>
<thead>
<tr>
<th>Training group</th>
<th>Before</th>
<th>After</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Six-minute Walking (m/s)</td>
<td>0.77</td>
<td>1.01</td>
<td>0.005</td>
</tr>
<tr>
<td>Perceived exertion (6–20)</td>
<td>15</td>
<td>13.5</td>
<td>ns</td>
</tr>
<tr>
<td>Timed Up and Go (s)</td>
<td>15</td>
<td>11</td>
<td>0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control group</th>
<th>Before</th>
<th>After</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Six-minute Walking (m/s)</td>
<td>0.85</td>
<td>0.90</td>
<td>ns</td>
</tr>
<tr>
<td>Perceived exertion (6–20)</td>
<td>15</td>
<td>16</td>
<td>ns</td>
</tr>
<tr>
<td>Timed Up and Go (s)</td>
<td>14</td>
<td>15</td>
<td>ns</td>
</tr>
</tbody>
</table>

ns, non significant.

Figure 3: (a) Individual values (m/s) of walking velocity before and after 10 weeks in training group (participants 1–10). (b) Individual values (m/s) of walking velocity before and after 10 weeks in control group (participants 11–17).
Results

Spasticity
There was no change in estimated spasticity after 10 weeks in neither the training group nor the control group. Initial values are presented in Table I. However, all individuals in the training group spontaneously expressed a feeling of reduced spasticity in their legs which was reported to last from two to six hours after training.

Range of motion
Median value of hip flexion in the training group was 120° (110–130) in the right leg at start and 130° (115–135) after 10 weeks; in the left leg 122° (105–130) at start and 130° (105–135) after 10 weeks. Median value of hip extension in the right leg was −5° (−25–0) at start and 0° (−15–5) after 10 weeks; in the left leg it was −7.5° (−20–0) at start and −5° (−15–0) after 10 weeks. In the training group there was a significant increase in hip flexion in both right ($p=0.02$) and left ($p=0.01$) legs and a significant increase in hip extension ($p=0.02$) in right legs. There was no difference in the control group nor between the groups concerning range of motion.

Isometric muscle strength
Median values and ranges of isometric strength in hip extensors ($p=0.005$ right, $p=0.006$ left) and hip abductors ($p=0.01$ right and left) in the training group. There was no change in isometric muscle strength in the control group or between the two groups.

Isokinetic muscle strength
Median values and ranges of isokinetic strength in knee extension in concentric and eccentric work and concentric peak torque in right and left legs at 30°/s are presented in Table III and at 90°/s in Table IV.

There was a significant increase in concentric work at 30°/s in both right ($p=0.01$) and left legs ($p=0.02$) over time but no significant increase in eccentric work in the training group was found. There was a significant increase in concentric peak torque over time in right ($p=0.03$) but not in left legs in the training group and no difference was found in the control group nor between the groups (Table III).

There was a significant increase over time in concentric work at 90°/s in the left leg ($p=0.05$) but not in the right leg and no significant increase in eccentric work was found in the training group. There was a significant increase over time in concentric peak torque in the right ($p=0.03$) but not in the left leg in the training group; no difference was found in the control group nor between the groups.

Gross Motor Function Measure
Median values of the GMFM test in the training group and in the control group are presented in Table V and Figures 2a and b. The total goal scores of dimensions D and E were significantly increased ($p=0.005$) in the training group but not in the control group. The increase in the training group was significant ($p=0.0005$) compared with the control group.

The correlation between GMFM and muscle strength was moderate to good ($r=0.56–0.70$, $p=0.02–0.002$).

Six-minute Walking test and perceived exertion
Median values of walking velocity and perceived exertion in the training group and the control group are presented in Table VI and Figures 3a and b. There was a significant increase in walking distance and walking velocity in the training group ($p=0.005$) but not in the control group. The increase was significant ($p=0.02$) compared with the control group.

The correlation between walking velocity and muscle

Figure 4: (a) Individual values (s) of Timed Up and Go (TUG) before and after 10 weeks in training group (participants 1–10). (b) Individual values (s) of Timed Up and Go (TUG) before and after 10 weeks in control group (participants 11–17).
strength was fair to good \((r=0.25–0.66, p=0.3–0.004)\).

The decrease in perceived exertion over time in the training group was not significant \((p=0.06)\). However, the decrease in the training group was significant \((p=0.005)\) compared with the values of the control group (Table VI).

**Timed Up and Go (TUG)**

Median values and ranges of the TUG test are presented in Table VI and Figures 4a and b. There was a significant decrease in time in the training group \((p=0.01)\) but there was no such difference in the control group. The increase in the training group was significant \((p=0.002)\) compared with values of the control group. The correlation between TUG and muscle strength was moderate to good \((r=0.45 \text{ to } 0.69, r=0.06–0.002)\).

**Discussion**

The findings in our study show that a 10-week progressive strength training programme which is focused on the lower extremities improves walking ability. However, all participants in this study could walk with or without walking aids and they all walked in a very typical way, with flexion, internal rotation and adduction in their hips and flexion in their knees. The antagonist muscles, hip abductors, and hip extensors are thus not normally activated and it could be assumed that they are weaker than in individuals with a normal walking pattern. Therefore, our hypothesis was confirmed that increased muscle strength in hip extensors and hip abductors would contribute to improved walking ability. The ankle plantar flexors were not measured for strength nor for passive range of motion. Many of the participants had tight contractures or deformities of different kinds and we found it difficult to perform adequate measurements and compare performance between or within the participants. However, the participants’ subjective opinions were that their ankles did not become tighter after the strength training period.

Muscle strength is one aspect of motor capacity and is limited to the amount of force generated, but also coordination of movement, balance, and motivation are important contributors to motor capacity (Bradley 1991). The increase in muscle strength in this study might be ascribed to an increase in neural adaptation (improved coordination between agonist and antagonist and increased activation of prime mover muscles) rather than in muscle mass as the training period lasted for only 10 weeks (Sale 1988). The individuals had not been training their lower extremities for a long time and might not fully have been utilizing their existing motor capacity (Andersson and Mattsson 2001). In this study there was a fair to good correlation between muscle strength and functional walking ability. Other effects of the strength training programme might have contributed to the improved walking ability. One effect might have been that the participants in the training group after 10 weeks had become more aware of their motor capacity, thus using it more functionally. To walk between the different training devices might also have improved functional mobility and balance.

Walking velocity was slower in all our participants compared with normal self-selected walking velocity in young adults, which is about 1.46 m/s (Shumway-Cook and Woollacott 1995). One person (participant 4) managed to walk at normal velocity (1.67 m/s) after the training period. One person (participant 2) walked 0.32 m/s after training and cannot be considered as a functional walker. Still, he increased his walking velocity and motor function and was able to move around in his apartment following the training period.

Podsiadlo and Richardson (1991) found that time taken to complete the TUG test was strongly correlated to the level of functional mobility. Older adults who were able to complete the task in less than 20 seconds were shown to be independent in activities of daily living and to walk at gait velocities of 0.50 m/s that should be sufficient for community mobility. In our study the median values for time taken to complete the TUG test in the training group were 15s before and 11s after the training period. One person in the training group (participant 6) increased his walking velocity from 0.37 to 0.50 m/s and decreased time in the TUG test from 39 to 20s, thus reaching the limits suggested by Podsiadlo and Richardson (1991). He also confirmed that he felt more secure when walking outside.

There was no change in spasticity after the training period, neither in the training group nor in the control group (Table I). These findings correspond well with the results of strength studies in stroke patients by Sharp and Brouwer (1997) and Teixeira-Salmela et al. (1999) and reinforce the opinion that strength training for individuals with spasticity is not contraindicated.

All participants had contractures in various ranges of motion in their hips and knees. Hip flexion and hip extension increased significantly in the training group. However, the differences were very small and could be considered to be within the limits of clinical measurement error. The participants received stretching after each training session and all of them stated that it was an important part of the training session. Their legs felt very relaxed afterwards. Studies have shown that about 80% of adults with CP have contractures in the lower extremities (Turk et al. 1997, Andersson and Mattsson 2001). Therefore, it is important to maintain range of motion as normal as possible as it is one of the prerequisites for functional walking ability.

There was no increase in eccentric work in this study and the reasons for that are unclear. Our training programme was not focussed on eccentric training of quadriceps and the testing situation could also have been a difficulty. MacPhail and Kramer (1995) suggested that children with more severe CP involvement were unable to use the isokinetic dynamometer in a proper manner and also that it was unclear whether additional practice would have improved their performance. Our participants seemed to have some difficulties ‘understanding’ how to resist the resistance pad of the isokinetic dynamometer, especially in eccentric muscle action, which could have contributed to the results. There has also been discussion about the most appropriate velocity for an isokinetic dynamometer when testing children with spastic CP. In a study by van den Berg-Emons et al. (1996) only 30°/s was selected in children with CP; it was suggested that extension peak torque could not be measured reliably at higher test velocities. The authors discussed that a possible explanation for this could be that coordination of agonist and antagonist muscles is more impaired at higher velocities. However, Ayalon et al. (2000) tested children with CP at 90°/s and found it highly reliable in the tested population.

All participants in the training group declared that their walking ability had improved and some of them were motivated to continue strength training. They also found the training positive and accessible. The improvements in the
training group were significant concerning GMFM, walking velocity, and TUG. However, further investigations are needed concerning the most appropriate intensity and loading in the strength training programme if the adult with CP wants to continue with strength training as a frequent activity. The ageing muscles of adults with spastic CP also need to be investigated in order to understand and give proper advice about frequent strength training and other forms of training.

Conclusion
The findings in our study show that a 10-week progressive strength training programme focussed on the lower extremities improves walking ability. Results show significant improvements in muscle strength, walking velocity, and gross motor function in standing and walking in the training group, but no change in spasticity was found. As the groups were small and heterogeneous no significant difference was seen between groups.

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References