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ORIGINAL REPORT

LONG-TERM BENEFITS OF PROGRESSIVE RESISTANCE TRAINING IN CHRONIC STROKE: A 4-YEAR FOLLOW-UP

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Objectives: **To evaluate the long-term benefits of progressive resistance training in chronic stroke.**
Design: **A 4-year follow-up of a randomized controlled trial of progressive resistance training.**
Subjects: **Eighteen women and men (mean age 66 (standard deviation 4) from the original group of 24 post-stroke participants.**
Methods: **The training group (*n*=11) had participated in supervised progressive resistance training of the knee extensors and flexors (80% of maximum) twice weekly for 10 weeks, whereas the control group (*n*=7) had continued their usual daily activities. Muscle strength was evaluated isotonically and isokinetically (60º/s; Biodex), muscle tone with the Modified Ashworth Scale, gait performance by the Timed Up and Go test, the Fast Gait Speed test and 6-Minute Walk test, and perceived participation with the Stroke Impact Scale (Participation domain).**
Results: **Four years after the intervention, the improvements in muscle strength in the training group were maintained, and there was no reduction in strength in the control group. Compared with baseline there were still significant between-group differences for both isotonic and isokinetic strength. No significant between-group differences were found in muscle tone, gait performance or perceived participation.**
Conclusion: **The results indicate that there is a long-term benefit of progressive resistance training in chronic stroke. This implies that progressive resistance training could be an effective training method to improve and maintain muscle strength in a long-term perspective.**

Key words: cerebrovascular accident; muscle; skeletal; strength training; gait; follow-up.

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INTRODUCTION

Muscle weakness in the lower limbs is a common impairment in chronic stroke (1, 2). It is associated with reduced walking ability, which, in turn, can have an adverse effect on perceived participation (3, 4). Over the past decade, there has been increased interest in evidence-based interventions to improve muscle strength, gait performance, perceived participation and quality of life (5, 6). One form of intervention that has proven effective is progressive resistance training (PRT), using free weights or specific strength training equipments with loads of 70–80% or more of maximum strength (3, 7–9). In a randomized controlled trial (*n*=24), we showed that knee muscle strength increased significantly after 10 weeks of PRT with no increase in muscle tone and the improvements were maintained at follow-up after 5 months. Both groups improved in gait performance, but at the follow-up 5 months after the intervention only Timed Up and Go (TUG) and perceived participation were significantly better for the training group (10). The effects of PRT in a longer perspective are unknown. The aim of this study, therefore, was to evaluate the long-term benefits of PRT in chronic stroke.

METHODS

Participants

Twenty-four women and men who participated in a randomized controlled trial of PRT in August 2005 to June 2006 (10) were invited to a 4-year follow-up. The participants were not informed about this follow-up until they received the invitation. Of the 24 participants, 1 woman and 1 man were unable to perform the assessments due to a new illness with a subsequent disability. Four women did not wish to participate, but described a general well-being when they were contacted. Thus, 5 women and 13 men (11 in the training group (TG) and 7 in the control group (CG)) agreed to participate. There were no significant differences at baseline or after the intervention between those who participated and those who did not participate in the 4-year follow-up. All participants were still community-dwelling, their mean age was 66 years (standard deviation (SD) 4 years), a mean of 69 months (SD 10) had elapsed since their stroke onset, and the mean time since the start of the intervention was 50 months (SD 3). The study was approved by the Ethics Research Committee of Lund University, Lund, Sweden (Dnr H4 163/2005).

Description of the intervention

A detailed description of the intervention has been presented elsewhere (10). In summary, the TG (*n*=15) participated in supervised PRT of the knee extensors and flexors (80% of maximum) twice weekly for 10 weeks using a Leg Extension/Curl Rehab exercise machine with pneumatic resistance (pressure resistance 10 bar) (HUR Ltd, Kokkola, Finland). The CG (*n*=9) continued their usual daily activities. Both groups were assessed before and after the intervention and at a follow-up after 5 months.

Assessments and outcome measures

Knee extension and flexion muscle strength was evaluated isotonically using the Leg Extension/Curl Rehab exercise machine and isokinetically (60º/s) using a Biodex® Multi-Joint System 3 PRO dynamometer (11).

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Increased muscle tone in the paretic lower limb was assessed with the Modified Ashworth scale (MAS) (12). Gait performance was assessed by the TUG, the Fast Gait Speed (FGS), and the 6-Minute Walk (6MW) tests (13). Perceived participation was assessed by the Stroke Impact Scale 3.0 (14) (SIS; Swedish version). In this study, as in our previous (10), we only used the SIS Participation domain, which addresses the impact of stroke on: work; social activities; quiet recreations; active recreations; role as a family member; religious activities; life control; and ability to help others. The same assessments were repeated at the 4-year follow-up; at this time the assessors were not blinded to the group assignment of the participants. All participants were interviewed about their physical activity pattern and what weekly activities they had engaged in during the past 3 months.

Statistical analysis

Differences between the 4-year follow-up assessment and: (*i*) baseline; (*ii*) after the intervention; and (*iii*) follow-up 5 months after the intervention were calculated for all 18 participants and each outcome measure. The between-group differences were analysed using the independent t-test for all outcome measures, except for MAS, where the Mann-Whitney *U* test was used. Differences within the TG and CG between the test sessions were calculated with the paired *t*-test, except for MAS, where the Wilcoxon signed-rank test was applied. All statistical tests were two-tailed. SPSS version 17.0 (SPSS Inc., 2004, Chicago, IL, USA) was used for the analysis. $p<0.05$ represented statistical significance.

RESULTS

Changes in outcome

Results from all 4 test occasions are presented in Tables I and II. In general, the improved muscle strength in the TG after 10 weeks of PRT was maintained at the 4-year follow-up, and the measurements for the CG were stable throughout. The percentage increases in muscle strength for the TG, from baseline to the 4-year follow-up, were between 30% and 70% for the isotonic muscle strength ($p<0.001$) and between 8% and 87% for the isokinetic muscle strength ($p<0.05$). For the CG, no significant changes were seen from baseline to the 4-year follow-up. The variations in muscle tone were negligible over time in both groups. The improvements in TUG, FGS and 6MW tests that were seen in the TG after the intervention were maintained at the 4-year follow-up. In the CG, the FGS was slower ($p<0.05$) and the distance for the 6MW test shorter ($p<0.05$) at the 4-year follow-up compared with after the intervention, indicating a significant deterioration in gait performance. There were no significant changes in perceived participation at the 4-year follow-up.

Table III presents the between-group differences for all outcome measures. There were significant between-group differences for all the isotonic measurements ($p<0.01$) and for the isokinetic knee extensor strength measurements ($p<0.05$) at the 4-year follow-up compared with baseline, but no other significant differences between the groups.

Weekly physical activity

The activity level during the past 3 months preceding the 4-year follow-up was similar in the TG and the CG. Most activities were performed during normal daily activities, such as walk-

Table I. *Knee muscle strength measurements (Nm) for the training group (TG;* n = *11) and the control group (CG;* n = *7) from the 4 test occasions*

	At baseline Mean (SD)	After intervention Mean (SD)	At 5-month follow-up Mean (SD)	At 4-year follow-up Mean (SD)
Non-paretic lower limb				
Isotonic knee extension				
TG	67.3 (11.8)	95.1 (17.2)	91.5 (17.9)	87.2 (20.3)
CG	65.6 (20.3)	70.6 (22.6)	68.9 (22.9)	67.0 (20.3)
Isotonic knee flexion				
TG	84.1 (15.8)	119.3 (20.1)	114.3 (20.8)	110.3 (21.2)
CG	84.0 (25.3)	89.2 (25.1)	90.0 (25.7)	89.8 (23.8)
Isokinetic knee extension				
TG	125.0 (37.6)	140.4 (30.9)	144.1 (36.2)	135.0 (37.0)
CG	130.1 (38.5)	124.3 (41.0)	123.9 (39.5)	114.1 (30.7)
Isokinetic knee flexion				
TG	57.2 (18.7)	70.1 (16.4)	66.6 (15.4)	68.6 (20.5)
CG	61.9 (25.9)	63.3 (29.0)	59.5 (23.9)	62.9 (23.9)
Paretic lower limb				
Isotonic knee extension				
TG	42.2 (12.7)	64.3 (15.6)	61.1 (19.2)	61.1 (15.8)
CG	41.8 (21.1)	42.9 (23.6)	43.9 (22.6)	43.7 (22.4)
Isotonic knee flexion				
TG	40.5 (12.0)	73.8 (23.5)	71.5 (23.9)	69.0 (23.8)
CG	54.8 (20.1)	57.2 (22.9)	56.6 (24.2)	55.0 (24.3)
Isokinetic knee extension				
TG	60.7 (25.1)	77.9 (32.4)	76.7 (32.0)	77.5 (24.2)
CG	62.2 (39.9)	57.7 (32.1)	60.8 (35.3)	57.4 (34.4)
Isokinetic knee flexion				
TG	12.0 (17.2)	23.7 (22.2)	26.7 (26.4)	22.4 (20.9)
CG	17.9 (17.4)	20.1 (18.2)	19.3 (15.3)	19.5 (19.2)

Nm: Newton metre; SD: standard deviation.

Table II. *Muscle tone, gait performance and perceived participation for the training group (TG;* n = *11) and the control group (CG;* n = *7) from the 4 test occasions*

	At baseline	After intervention	At 5-month follow-up	At 4-year follow-up
Muscle tone				
Modified Ashworth Scale, points, median (range)				
TG	2 (0–8)	1 (0–5)	2 (0–5)	2 (0–7)
CG	3 (0–8)	1 (0–4)	1 (0–10)	2 (0–8)
Gait performance				
Timed Up and Go, s, mean (SD)[a]				
TG	25.5 (12.1)	21.1 (8.6)	20.9 (8.1)	20.5 (8.7)
CG	27.5 (16.7)	25.0 (15.5)	28.1 (20.9)	27.7 (21.8)
Fast Gait Speed, 10 m; m/s				
TG	0.86 (0.47)	0.96 (0.40)	0.96 (0.41)	0.92 (0.40)
CG	0.86 (0.51)	0.90 (0.57)	0.86 (0.41)	0.73 (0.45)
6-Minute Walk test, m				
TG	252 (132)	279 (124)	283 (132)	275 (135)
CG	238 (138)	249 (150)	233 (144)	223 (137)
Participation				
Stroke Impact Scale, Domain 8, %, mean (SD)				
TG	59.7 (17.8)	66.5 (14.6)	57.7 (15.5)	63.1 (18.0)
CG	55.4 (19.4)	58.9 (21.8)	48.2 (22.7)	62.9 (15.2)

[a]Low values indicate a better performance.
SD: standard deviation.

Table III. *Mean differences between the changes in the training group (TG;* n = *11) and the control group (CG;* n = *7) for all outcome measurements*

	4-year follow-up vs baseline	4-year follow-up vs after intervention	4-year follow-up vs 5-month follow-up
Non-paretic lower limb, Nm			
Isotonic knee extension	18.5**	–4.3	–2.4
Isotonic knee flexion	20.4**	–9.6	–3.8
Isokinetic knee extension	26.0*	4.8	0.7
Isokinetic knee flexion	10.4	–1.1	–1.4
Paretic lower limb, Nm			
Isotonic knee extension	17.0**	–4.0	0.2
Isotonic knee flexion	28.3***	–2.6	–0.9
Isokinetic knee extension	21.6*	–0.1	4.1
Isokinetic knee flexion	8.8	–0.7	–4.5
Muscle tone, Modified Ashworth Scale; pointsa	0.9	0.5	1.0
Gait performance test			
Timed Up and Go (s)[a]	–5.2	–3.3	0.0
Fast Gait Speed (m/s)	0.2	0.1	0.1
6-Minute Walk test (m)	38	22	2
Participation, Stroke Impact Scale, Domain 8; %	–4.1	–7.4	–9.3

$*p<0.05$; $**p<0.01$; $***p<0.001$.
[a]Negative values indicate a better performance for the TG.
Nm: Newton metre.

ing. In both groups, approximately 70% of participants were physically active 3–5 days per week, otherwise 1–2 days per week; typical activities were walking, biking or taking part in fitness classes.

DISCUSSION

This is, to the best of our knowledge, the first study to evaluate the long-term benefits of PRT in chronic stroke. Four years after the intervention, the improvements in muscle strength in the TG were maintained, and there was no reduction in strength in the CG. Compared with baseline, there were significant between-group differences for both isotonic and isokinetic strength, but no significant between-group differences for the other measurements.

Despite being 4 years older, the TG had maintained their improvements in knee muscle strength and the CG had not deteriorated. Even if both groups had maintained their strength, the between-group difference in isokinetic knee flexor strength present after PRT had disappeared at the 4-year follow-up. It may be that activities performed during a normal day activate the extensor muscles more than the flexors, and thereby contribute to the maintained strength in some muscles, but are not enough to prevent a loss in others.

For most participants, muscle tone was low in the paretic lower limb. There were no significant differences between the groups at any time and no significant changes compared with baseline, which also indicates that post-stroke muscle tone is stable over time.

The long-term effects of PRT on gait performance were not as consistent as that on muscle strength. There were no significant between-group differences in any of the gait performance tests at the 4-year follow-up. However, the improved gait performance in the TG after the intervention was maintained, whereas both the FGS and the 6MW tests had deteriorated significantly in the CG at the 4-year follow-up compared with baseline. As both groups were rather active, the maintained gait performance in the TG, as compared with the deterioration in the CG, could not be explained simply by a difference in their physical activity level. A possibility is that the improved muscle strength after PRT was maintained because the participants in the TG preserved their mobility, which, in turn, had a positive effect on their muscle strength. This bi-directional transfer of improved body functions and increased activity level is a key element in the International Classification of Functioning, Disability and Health (15), and is of great importance for the planning of appropriate rehabilitation strategies.

For SIS participation, there were small changes over time, but no significant between-group differences. However, this outcome measure may not be sensitive enough to evaluate small changes in perceived participation for individuals in a chronic phase after stroke.

The participants in the TG and the CG reported a similar level of low to moderate weekly physical activity during the 3 months preceding the 4-year follow-up. This is important, as it can decrease restrictions in perceived participation, and reduce the risk of secondary complications, such as diabetes, hypertension and coronary heart disease (16).

Few studies have evaluated the long-term effects of intensive therapy in chronic stroke. We have assessed the long-term benefits of constraint-induced movement therapy (CIMT) for upper extremity after stroke (17). Four years after a short period of CIMT, hand function was maintained and self-reported use of the more affected hand was still significantly higher than before training. Thus, it seems that intensive training can increase both strength and functional ability in individuals with chronic stroke, and that improvements can be maintained for several years.

Better knowledge of the long-term effects of different interventions after stroke is important for rehabilitation teams, to enable them to give appropriate recommendations about physical training. This study implies that PRT should be part of rehabilitation strategies in chronic stroke. An important aspect, beyond the scope of this study, is the probable need for both high-intensity repetitive training and task-oriented training to optimize mobility and gait performance in chronic stroke.

An obvious limitation was the small sample size; only 18 of the 24 individuals from the original randomized controlled trial were assessed at the 4-year follow-up. As there was no significant difference between the participants and the non-participants at any time-point, the small drop-out may not have affected the overall results.

In conclusion, this study indicates that there is a long-term benefit of PRT in chronic stroke. Thus, PRT seems to be an effective training method to improve and maintain muscle strength in a long-term perspective, and this supports its inclusion in post-stroke rehabilitation programmes. Further research with larger numbers of subjects is needed before we can make more definitive recommendations about the intensity and duration of PRT in chronic stroke.

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