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The effects of progressive resistance training for children with cerebral palsy

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Objectives: To investigate the effects of progressive resistance training of quadriceps and hamstrings muscles in children with cerebral palsy (CP).
Design: Pilot study using a repeated measures design with measurements at baseline, immediately after six weeks training then at four-week follow-up.
Setting: The project was undertaken within the physiotherapy department of two special schools in Glasgow.
Subjects: A convenience sample of eight children aged between six and 12 years, with hypertonic CP.
Intervention: The subjects participated three times per week in a six-week, progressive, free-weight, strengthening programme.
Outcome measures: Maximum isometric muscle strength and resistance to passive stretch were measured with a hand-held myometer. The Gross Motor Function Measure and a 10-metre timed walking test, were used to assess function and gait parameters respectively.
Results: Muscle strength increased, with the quadriceps to hamstrings strength ratio moving towards normal. These changes were retained at follow-up. Muscle tone decreased and continued to decrease to follow-up. The standing (D) and walking, running and jumping (E) goal areas of the Gross Motor Function Measure showed improvement that continued towards follow-up. Walking speed and step rate increased.
Conclusions: A future large-scale randomized controlled study would be of value to substantiate these results as the small convenience sample and lack of control group limit this study. However, the finding that no adverse effect accompanied the positive outcomes in strength and function may encourage clinicians to consider resistance training alongside standard therapeutic interventions.

Introduction

Cerebral palsy (CP) is a nonprogressive, though not unchanging, neurological disorder affecting approximately 1.5–2.5 per 1000 live births. Significant weakness has been identified in children with CP by various authors.[1–3] Strength training has been regarded as controversial and inappropriate, due to concerns that it would increase abnormal muscle tone and movement abnormalities.[4,5]

Nevertheless, some studies have shown that strength gains can be achieved in children with CP, without adverse effects. McCubbin and

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Shasby[6] in a randomized controlled trial ($n = 30$) described a significant increase in movement speed and muscle torque in the resistance trained group with no adverse effects. Other authors reported that gains in strength could be achieved with resistance training of thigh musculature for CP without adverse effects on movement or spasticity.[7,8] Since the present study was undertaken, other trials with CP children[9,10] and systematic reviews of strength training with CP[11] and stroke survivors[12] have all shown improvements in strength without any untoward effects on spasticity, reinforcing the belief that strength training can be regarded as a safe and effective intervention for patients who have neurological disorders.

Quadriceps and hamstrings muscles have a key role in knee joint control and have been found to be adversely affected in CP.[7,8,13] There is a paucity of studies involving progressive resistance training (PRT) of both muscle groups and functional outcomes in these subjects.

This study aimed to investigate the effects of progressive resistance training of hamstrings and quadriceps muscles, with regard to strength, muscle tone and functional outcomes in bilaterally affected children with hypertonic cerebral palsy.

Method

This pilot study was an experimental, repeated measures design. Yorkhill NHS Trust Ethics Committee granted approval for the study and a convenience sample ($n = 8$) was recruited from two special schools in Glasgow. Informed parental consent (child consent where applicable) was obtained. Data were collected at baseline, after six weeks training and at four-week follow-up with the order of testing of the different parameters randomized to reduce order effects inherent in this design. To reduce bias, an assessor who was not the treating therapist and not aware of the study design, undertook the Gross Motor Function Measure (GMFM) testing without review of previous scores.[14] Data from the other outcomes were gathered by the researcher, but were not reviewed prior to repeat testing nor were scores seen during data collection.

Criteria for inclusion in the study were: a consultant's diagnosis of bilateral hypertonic CP; aged 5–12 years; ability to walk with or without aids; ability to follow simple instructions; provision of informed consent. Exclusion criteria included: debilitating illness before or during the study; surgical or orthopaedic procedures during, or up to six months prior to the study; medication changes that could affect muscle strength or tone; cardiac or respiratory conditions that may be affected by exercise. Subjects' age, height, weight and Gross Motor Classification System level[15] were recorded at the start.

Dimensions 'D' and 'E' of the GMFM were used to assess standing and walking, running and jumping. This valid, reliable and sensitive test was applied in accordance with the manual's detailed guidelines.[14,16]

The 10-metre timed walking test was used to measure the walking ability of the children at their self-selected and fastest attainable speeds.[17] Children used their usual footwear and appliances, and the test was video-recorded to improve reliability and sensitivity.[18] Mean values for walking speed, cadence and step length were calculated from three trials.

The Penny and Giles Transducer Myometer (Penny & Giles, Christchurch, Dorset, UK) has been established as a valid and reliable tool for strength testing and was used to assess isometric muscle strength.[19,20] Its use was standardized in accordance with the literature.[19–23] The 'hold' technique was used after a submaximal practice. The mean of three trials (at least 1 min rest between) was taken for each muscle group.

Quadriceps maximum isometric muscle strength was measured with each child sitting in a chair with armrests, a lap strap secured the pelvis and the back was fully supported. Subjects lay prone with a pillow under the thorax for hamstrings muscle testing. For both muscles the knee was positioned at 90 degrees and the myometer head positioned just proximal to the lateral maleolus.

Muscle tone was assessed by testing the resistance to passive stretch (RPS) using the myometer.[24,25] Piloting and practice was undertaken to improve reliability of measurements as little literature exists for this method. The mean of three trials was used for analysis. Subjects were positioned in side-lying on a variable-height plinth with a smooth, low-friction board used to fully support the test limb with the knee in a semi-flexed position. The test limb was passively moved through the available range of movement (ROM) to familiarize the subject, then with the myometer placed as for strength testing, the limb was again passively moved through the available range via the transducer head. Subjects were asked to keep their body still and not help or resist the movement. Speed of passive movement was set by a metronome at 120 beats per minute (60 degrees/s).

Free weights (Physio Med Services Ltd., Glossop, England and Weider by Icon Health & Fitness, Utah, USA) were used to provide resistance for the strength training in the form of adjustable weight cuffs attached by Velcro straps to the subjects' ankles. Weight was increased by increments of 0.25 kg and 0.75 kg.

For training, the children were positioned as for muscle strength testing with free weights attached to the ankle. Exercising was completed in one position before changing to the other; this starting position and the limb trained first was varied at each session to reduce order effects. The training weight (TW) used in this study was 65% of the mean maximum isometric muscle strength value for each individual.[8,26]

Maximum strength was re-measured every two weeks during the six-week programme and the TW reset at 65% of the new value. At each TW the children progressed from three sets of five repetitions, to four sets of five, then three sets of ten as the number of repetitions became easy.[27] At each session the TW and repetitions were recorded along with the child's well-being, any prior discomfort and compliance to the session.

Training was undertaken in the physiotherapy gymnasium of each school, three times a week with at least one day's rest between sessions.[27] Concentric and eccentric contractions in mid to inner range muscle work were utilized to enhance muscle responses.[28]

Minitab version 12.1 and SPSS version 11.5 were used to analyse the data and the level of significance was set at 5%. A repeated measures parametric ANOVA design, with time as the main factor allowed the comparison of means at the three measurement times (baseline, post training and four-week follow-up). The ANOVA diagnostics were performed and confirmed the appropriate use of the parametric model. Tukey's HSD post-hoc test was applied where appropriate to further analyse the time factor.[29]

Results

Four boys and four girls, all level III on the Gross Motor Classification System,[15] completed between 14 and 16 training sessions out of 18, absence from school being the only reason for omissions. Data sets are complete for all subjects. The mean age for subjects was 8 years 5 months (range: 6 years 10 months to 11 years 2 months), the mean height was 116.75 cm (111–132.5 cm) and the mean weight was 26.6 kg (18–40.6 kg). Seven children wore ankle-foot orthoses with or without additional walking aids; quadruped sticks (two children), Kaye-walkers (four children). One child used elbow crutches only.

Means, standard deviations, ANOVA and post-hoc p-value results for all variables are presented in Table 1.

The mean muscle strength of quadriceps and hamstrings all showed statistically significant results. Post-hoc analysis found that all pre/post and all pre/follow-up comparisons were significant, indicating that the post-training strength was retained at follow-up. The ratio of quadriceps to hamstrings strength moved closer to normal values (i.e., 60:40).[30] Pretraining values for right and left limbs were 74:26 and 75:25, respectively, while post-training values had changed to right limb 67:33 and left limb 68:32.

Resistance to passive stretch results showed a reduction at post training that continued to decrease to follow-up. The passive stretch for left quadriceps and hamstrings were, over time, found to be statistically significant. Post-hoc analysis indicated that only the pre/follow-up comparisons were statistically significant.

The trends observed in temporal distance (TD) walking measurements indicated that each parameter improved after training, regressed towards follow-up and, apart from 'fast step length', did not return to baseline values.

Self-selected walking speed showed an increase after strength training and the ability to increase to fast walking speed was also enhanced. Both walking speeds decreased in the follow-up period

Table 1 Results of strengthening for cerebral palsy

Muscle strength (kg of force)	Pre training Mean (SD)	Post training Mean (SD)	Follow-up Mean (SD)	Anova *p*-value	Tukey *p*-value pre/post	Tukey *p*-value pre/follow-up
Quadriceps right	6.7 (3.2)	9.3 (2.9)	8.9 (2.9)	0.008*	0.010	0.030
Quadriceps left	7.0 (3.0)	9.3 (2.7)	9.7 (2.7)	< 0.001*	0.002	0.001
Hamstrings right	2.4 (1.8)	4.5 (2.8)	4.5 (2.7)	< 0.001*	0.001	0.001
Hamstrings left	2.3 (1.9)	4.3 (2.2)	4.6 (2.2)	< 0.001*	< 0.001	< 0.001
Passive stretch (kg of force)						
Quadriceps right	2.0 (1.0)	1.9 (0.6)	1.6 (0.8)	0.315		
Quadriceps left	2.5 (1.5)	2.0 (0.9)	1.7 (0.9)	0.027*	NS	0.022
Hamstrings right	2.4 (0.8)	2.1 (0.5)	1.9 (0.2)	0.094		
Hamstrings left	1.9 (0.8)	1.6 (0.4)	1.5 (0.5)	0.039*	NS	0.037
Gait results						
SS speed (m/s)	0.55 (0.22)	0.67 (0.13)	0.62 (0.22)	0.059		
Fast speed (m/s)	0.77 (0.25)	0.87 (0.19)	0.79 (0.25)	0.126		
SS cadence (steps/min)	93.96 (18.29)	108.87 (12.24)	105.64 (15.26)	0.007*	0.030	NS
Fast cadence (steps/min)	115.46 (13.60)	127.38 (15.72)	125.08 (16.62)	0.117		
SS step length (m)	0.34 (0.07)	0.37 (0.05)	0.34 (0.08)	0.123		
Fast step length (m)	0.39 (0.1)	0.41 (0.07)	0.37 (0.08)	0.127		
GMFM dimensions						
D (%)	47	48	50	0.234		
E (%)	30	34	35	0.020*	NS	0.022

SD, standard deviation; SS, self-selected; %, percentage of possible for goal area; D, standing; E, walking, running and jumping.
*Statistically significant ANOVA *p*-value; NS, nonsignificant.

but remained above baseline. Cadence, which was increased post training, decreased in the follow-up period but remained well above baseline. The self-selected cadence parameter achieved statistical significance over time ($p = 0.007$) and the post-hoc test identified the pre/post comparison as being significant ($p = 0.030$).

Subjects relied on increasing cadence more than step length to achieve increased speed. This was particularly evident at follow-up. Step length was increased after training at self-selected walking speed but remained the same for fast walking.

The GMFM showed improvement in both dimensions after training with further improvement at four-week follow-up. Statistically significant changes were seen in dimension 'E' ($p = 0.020$), related to walking, and post-hoc analysis indicated that the significant change was from pre training to follow-up ($p = 0.022$). In contrast, in dimension 'D', related to standing, no significance was found ($p = 0.234$).

Discussion

The children enjoyed exercising and there were no reports of joint discomfort. The TW and progression appeared appropriate and safe and is in agreement with findings in similar studies.[8,31] Resetting the TW two weekly was adequate as each child had attained maximum repetitions prior to retesting, as in the study by Damiano and Abel.[8] The positive responses to free-weight training as shown in this study suggest that it may be more appropriate for children with CP than the isokinetic-training mode used by MacPhail and Kramer.[7]

The children all made significant strength gains that were similar to those reported by McCubbin and Shasby.[6] Strength gains were retained until follow-up, possibly due to the children making use of their acquired strength functionally.[32] A longer follow-up period would have allowed comparison with MacPhail and Kramer who noted a detraining effect.[7]

Clinical messages

- Progressive resistance training would appear to be a safe, accessible and effective means to increase muscle strength in children with cerebral palsy.
- There is evidence of improved walking ability following strengthening of quadriceps and hamstrings muscles.

The post-training muscle strength ratio moved closer to a normal value and this may have impacted on functional performance in this group by assisting with new motor skill acquisition. By only exercising quadriceps muscle, previous researchers may have been moving the ratio further out of balance in favour of quadriceps, potentially impacting on functional outcomes.[1,8,31]

Downward trends in RPS measurements were an unexpected outcome as others studies reported no change.[6–8] The use of less sensitive outcome measures such as the Ashworth Scale may not have been adequate to detect a small change in RPS in previous studies.[7]

The enhanced effects in the TD walking parameters in the present study compared favourably with other studies. Neither MacPhail and Kramer[7] nor Damiano *et al.*[31] reported any statistically significant TD changes, whereas self-selected cadence in this study reached statistical significance. The training of mid to inner range work in both quadriceps and hamstring muscles may have accounted for the enhanced effects seen in this study.

The children's increase in self-selected walking speed post training was achieved by a combination of increased cadence and step length. However, the increased speed at fast walking was achieved through increased cadence alone. This may have been due to the children having reached the limit of their ability to increase step length, because of anatomical and biomechanical limitations.[33] At follow-up the fast walking step length decreased to less than baseline values even though the ability to attain a greater speed was maintained. This may be accounted for by the subjects' greater reliance on increased cadence.

This study is in agreement with others who reported statistically significant GMFM gains immediately post training.[7,8] However, no follow-up results were reported. The present study's GMFM follow-up results could be explained through enhanced strength and lowered RPS, creating an environment for continued gross motor development and further drop in RPS without further training.

It is recognized by the authors that the results and statistical power of this pilot study are limited by the small numbers within the convenience sample and the lack of any control group, so the results should be viewed with caution. In addition the measurement of RPS requires further research and development. Nevertheless, arguments against resistance training would appear to be unsubstantiated in that there was no evidence of adverse effects.

In a subject group such as this, the extent of GMFM improvements was greater than those normally anticipated, without intervention, at this stage of the children's development and within the time frame involved.[14] It is therefore not unreasonable to conclude that the experimental intervention may have been responsible, at least in part, for the observed changes.

In conclusion, free-weight progressive resistance training can be viewed as an accessible, practical and safe method to increase knee muscle strength and positively alter walking ability in this group of children.

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