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Observations of Performance and Body Composition Following 8-weeks of Progressive Resistance Training in Participants With Cerebral Palsy

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ABSTRACT

Purpose: To observe the effects of progressive resistance training on performance and body composition in participants with cerebral palsy.

Methods: Four quadriplegic (3 male, 1 female) and two hemiplegic (2 female) participants (22 ± 5 yr, mean ± SD) completed moderate to high intensity resistance training 2-3 days a week for 8-weeks. Strength training programs were developed for each participant based on their physical ability. Measurements of exercise performance and body composition (InBody 270 & S10) were collected prior to and following training. Data from all participants was pooled, and samples with 5-6 subjects were analyzed using a paired t-test with significance set at $p < 0.05$.

Results: Measurements of muscular fitness improved, including plank performance (pre: 64 ± 40, post: 95 ± 61 s, n = 6), supine sled leg press 1RM (pre: 225 ± 69, post: 378 ± 124 lb, n = 6) and bench/sled press 1RM (pre: 92 ± 54, post: 115 ± 58 lb, n = 5). There was no change in peak sprint capacity (pre: 89 ± 32, post: 96 ± 29 W, n = 5) or peak aerobic capacity (pre: 303 ± 136, post: 370 ± 246 s, n = 4). Measurements of body weight (pre: 151 ± 40, post: 151 ± 42 lb, n = 6) and skeletal muscle mass (pre: 53 ± 8, post: 54 ± 9 lb, n = 6) were unchanged following training.

Conclusion: Preliminary data is encouraging that the unique and challenging strength training program employed with these participants can be utilized to gain meaningful improvements in muscular fitness. However, a larger sample size and longer training period may be necessary to significantly increase muscle mass.

Keywords: Cerebral palsy; exercise; Hypertrophy; Strength training

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Introduction

Cerebral palsy (CP) is a neurodevelopmental condition that can effect muscle tone, movement and coordination in one or multiple limbs. These impairments often contribute to inadequate muscle development [1,2], and as a result individuals with CP can struggle with activities of daily living (ADL) and tend to report lower levels of daily physical activity [3,4]. Thus, exercise can be a valuable treatment that could in part offset these limitations [5].

There is a growing body of evidence that chronic resistance training in participants with CP can significantly improve dynamic strength [6,7,8,9,10,11], isokinetic strength [12,13] and isometric strength [13,14]. In addition, there is preliminary evidence that physical benefits gained during training sessions may be maintained for weeks after training has ceased [15].

It is still to be determined what specific adaptations are associated with improved and lasting muscular strength and function following training, but it has been suspected that limited strength in people with CP is due to neuromuscular deficiencies including spasticity, neural drive, coordination of contractions and/or muscle agonist deficiencies [16,,17,18}. These deficiencies may limit similar gains in muscle mass to people without CP, so determining training programs that stimulate muscle hypertrophy would be advantageous. To date, there have only been a few observations of lower body muscle morphology following chronic resistance training [19,20], and further observations are necessary to determine if whole body hypertrophy occurs following resistance training in people with CP and what training methods optimize strength and muscle hypertrophy. Therefore, the purpose of our study was to observe the effects of a unique upper and lower body 8-week progressive resistance training program on markers of performance and body composition in adolescents and young adults with CP.

Methods

Participants

Eight participants volunteered to complete the study and six completed the assessments and training. This included four quadriplegic (QP) and two hemiplegic (HP) individuals. Descriptive characteristics can be found in Table 1. Subjects were fully informed of the purpose of the study and of potential risks before giving written and verbal consent. This study was approved by the Institutional Review Board at Fitchburg State University.

Table 1. Participant characteristics and training frequency.

Particpiant	Age (years)	Training frequency (days/week)	Particpiant	Age (years)	Training frequency (days/week)
1-HP (female)	15	2	1-QP (female)	23	2
2-HP (female)	19	2	2-QP (male)	19	3
			3-QP (male)	24	3
			4-QP (male)	30	2

HP, hemiplegic; QP, quadraplegic.

Study design

Subjects visited the training center prior to and following training to complete muscular fitness, peak power, peak aerobic capacity and body composition assessments. These assessments took place in a single day and were repeated following training.

Following the pre-training assessments, participants completed muscular strength training 2-3 days a week for 8-weeks. Each training session lasted approximately 60-minutes. Because of the heterogeneity of the participants physical abilities, exercises and assessments were modified when neccesary to accommodate each participant.

Muscular fitness assessments

Muscular fitness assessments were conducted to assess leg strength, upper body strength and isometric endurance. Following a brief warm-up the supine sled leg press was performed first to determine 1-repetition maximum (1RM) leg strength (Figure 1). Subjects laid on their back with the soles of their shoes on the low handles of a Prowler Sled. Knees were bent to 90° and subjects pushed the sled extending their knees and hips without lifting their hips off the ground to complete one repetition. Subjects completed 5-8 one repetition sets of increasing weight prior to reaching 1RM.

Following the leg press, participants completed one of two assessments of upper-body strength. Following a brief warm-up a horizontal press was utilized in participants with previous bench press experience. These subjects (n = 2) were strapped to the bench using a weightlifting belt for stability. Following a brief warm-up, subjects completed about 4-5 sets decreasing repetitions each set until reaching 1RM. Subjects (n = 3) who had no bench press experience completed a unique upper body assessment using a staggered stance sled press. Participants placed one foot in front of the other, leaned into the sled until their elbows were in line with their ribcage and then pressed the sled until their arms were fully extended. Subjects completed 4-5 sets of one repetition prior to reaching 1RM.

Next, an isometric plank test was completed to assess muscular endurance. HP participants completed a standard plank exercise propped on their toes and forearms with their elbows directly below their shoulders. Subjects were asked to hold the position as long as possible with their knees, hips, torso and neck in a straight alignment. Participants with knee contractures that were unable to straighten their legs enough to perform a standard plank completed a high plank propped on their toes and hands with extended elbow similar to a push-up position.

Peak power and peak aerobic capacity

Participants completed a peak power test. Following a brief warm-up, five of the six subjects completed a 30-second maximal effort on a rowing machine (n = 5, *Concept2 Model D Rower*). One subject that was unable to sit upright on the rowing machine completed the 30-second test on a seated ski ergometer using a posterior walker (n = 1, *Concept2 Wall-Mounted Ski Ergometer*). Instantaneous maximal power and distance completed was recorded.

Cardiorespiratory endurance was measured during a ramped treadmill (*Cybex 750T*) protocol modified from Verschuren et. al. [21]. Following a brief low intensity warm-up, participants began walking at a slow speed (1.0-2.0 mph) at a 0% grade. The speed of the treadmill was increased by 0.2 mph every 30-seconds and participants were encouraged to continue for as long as possible. The test was terminated when participants requested to stop.

Body composition

Whole body and segmental body composition assessments were conducted prior to and following training through one of two dual signal bioelectrical impedance analysis (BIA) systems. All participants were asked to come to the laboratory well-hydrated and on an empty stomach. The *InBody 270* BIA was used to test participants that could stand and grasp the hand electrodes on their own and the remaining participants were assessed using the *InBody S10* BIA in the supine position using electrodes on the ankles, thumbs and middle fingers. Body weight in participants that could not stand was measured on a platform scale.

Muscular fitness training

Whole body muscular fitness training was completed by participants either two or three days a week based on training status. Each participant trained for about 60-minutes a session and exercises were individually designed based on the subject's ability. Exercises included the leg press (Prowler Sled), hamstring curls, squats, step-ups, Glute bridge variations, upper body press (dumbbell or barbell), plank variations, sit-ups, Pallof press, hip abduction, isometric adduction and varied biceps, triceps, back and calf exercises. Subjects completed 3-4 sets and 6-12 repetitions for each exercise. Sessions progressed on an individual basis through increases in volume of work and decreased rest between sets.

Data from all participants was pooled and the mean and standard deviation (SD) were determined. Performance and body composition and measurements in samples that included 5-6 participants were analyzed using a two-tailed paired t-test with a significance set at $p < 0.05$.

Results

Participants trained 2-3 times a week completing 8-weeks of training. Training volume increased periodically throughout the program. Assessments were completed within 5-days before and after training.

Table 2. Descriptive characteristics prior to and following training.

Participant	Weight (lb)		% Body fat		Skeletal muscle mass (lb)	
	Pre	Post	Pre	Post	Pre	Post
1-HP	109	108	18	20	49	48
2-HP	167	169	40	40	55	56
1-QP	110	108	25	20	45	47
2-QP	145	145	34	34	53	52
3-QP	216	219	44	42	67	71
4-QP	156	156	42	39	50	53
Mean ± SD:	151 ± 40	151 ± 42	34 ± 10	33 ± 10	53 ± 8	54 ± 9

Pre, pre-training; Post, post-training; lb, pounds; SD, standard deviation. * Significantly different than pre-training ($p < 0.05$).

Body composition

Percent body water was similar between pre- and post-training trials (Pre = 49.7 ± 6.4, Post = 49.7 ± 7.4 %). Following 8-weeks of training body weight, % body fat and skeletal muscle mass were unchanged following training (Table 2). Regional measurements of lean mass in the right arm (Pre = 5.7 ± 1.2, Post = 5.9 ± 1.5 lb), left arm (Pre = 5.5 ± 0.9, Post = 5.7 ± 1.2 lb), trunk (Pre = 47.3 ± 6.0, Post = 47.8 ± 6.8 lb), right leg (Pre = 14.1 ± 3.9, Post = 14.2 ± 3.9 lb) and left leg (Pre = 13.9 ± 3.8, Post = 13.8 ± 3.3 lb) were also unchanged following training.

Performance measurements

Leg press and upper body 1RM increased following training (Table 3). In addition, isometric muscular endurance performance assessed by the traditional (n = 2) and high plank (N = 4) performance improved in all participants (Table 3).

Peak power (Table 4) and distance covered during the 30-second maximal test (Pre = 90.2 ± 28.7, Post = 97.3 ± 25.7 m) did not improve following training. Mean pre- and post-training peak aerobic capacity (n = 4) were not analyzed, but individual results can be found in Table 4.

Table 3. Muscular fitness results prior to and following training.

Participant	Isometric muscular endurance		Leg strength		Upper-body strength	
	Plank (s)		Supine Leg Press 1RM (lb)		Bench Press 1RM (lb)	
	Pre	Post	Pre	Post	Pre	Post
1-HP	61	70	250	300	70	90
2-HP	18	60	280	390	N/A	N/A
	High Plank (s)				Arm-Sled Press 1RM (lb)	
1-QP	30	47	100	270	120	160
2-QP	117	181	220	500	160	160
3-QP	31	46	290	550	95	145
4-QP	105	165	210	260	15	25
Mean ± SD:	64 ± 40	95 ± 61*	225 ± 69	378 ± 124*	92 ± 54	115 ± 88*

Pre, pre-training; Post, post-training; SD, standard deviation; s, seconds; 1RM, 1-repitition maximum; lb, pounds. * Significantly different than pre-training ($p < 0.05$).

Table 4. Peak power and aerobic capacity prior to and following training.

Participant	Peak power (W)		Aerobic capacity (s)	
	Pre	Post	Pre	Post
1-HP	123	121	489	720
2-HP	82	177	300	360
1-QP	15	26	280	313
2-QP	291	253	105	145
3-QP	114 [a]	129 [a]	N/A	N/A
4-QP	67	82	N/A	N/A
Mean ± SD:	89 ± 32	96 ± 29	303 ± 136	370 ± 246

HP, hemiplegic; QP, quadraplegic; Pre, pre-training; Post, post-training; W, watts; s, seconds; SD, standard deviation; [a], completed on ski ergometer; * Significantly different than pre-training ($p < 0.05$).

Discussion

The current study examined the effects of an 8-week progressive resistance training program on performance and body composition in individuals with CP. A well-rounded and unique training program was utilized and resulted in significant improvements in upper and lower body strength, but there was no change in skeletal muscle mass.

This study utilized a novel method to train and measure leg strength in those with CP. The supine sled leg press was modified to train the quadriceps through knee extension without stability demands. Modifications such as a ball placed between the knees, a pad placed under the head and feet strapped to the handles of the sled allowed some participants to improve alignment and pressing mechanics (Figure 1).

Figure 1: Participant completing a modified supine leg press

In addition, many other modifications were made based on the individual's mobility and dexterity to develop a well-rounded and challenging training program. Sessions included 8-10 exercises (2 movement preparation, 6-7 strength training movements, and a conditioning protocol) working at moderate to high training intensities.

Muscular fitness

Following 8-weeks of resistance training there were substantial improvements in lower (68% increase) and upper body (25% increase) strength. These results were consistent with other training programs lasting 6-12 weeks, and adds to the growing evidence that resistance training can improve physical strength in individuals with CP [6,7,8,9,10,11,12,13,14].

While the research includes many different types of advantageous training programs for those with CP, optimal exercise patterns have not yet universally emerged [5,22]. Current research in addition to our findings suggest that whole body progressive resistance training programs at a moderate to high intensity provide substantial benefits in muscular strength for those with CP and offer a template for practitioners to optimize training programs.

Part of optimizing training programs is dependent on the goals for the participant and may include: improving strength, gait and mobility, or body composition. Studies assessing changes in strength using isometric training programs have been beneficial to improve strength, but there is an abundance of evidence in seemingly healthy individuals that dynamic resistance training results in greater gains in muscular fitness than isometric exercises. This is likely due to the ability to train at a higher intensity [23] during dynamic training. While there is no current comparable evidence that this trend would be similar in people with CP, it is likely that the added overload during dynamic exercise would yield greater benefits than isometric training.

Improvements in gait and mobility have been observed with some isokinetic, isometric and dynamic resistance exercise training programs lasting 6-12 weeks [8,9,13,14,15,20], but some studies did not report improvements [6,19,24]. These results suggest that multiple resistance training modalities can improve ADL and that while individuals with CP appear to respond well to varying types of resistance training, not all programs enhance the same measurements of performance. Practitioners have numerous tools available to develop beneficial training programs and the current research in the field offers glimpses of optimal strategies to reach specific goals of interest.

Developing resistance training programs that can enhance muscle mass for those with CP would be a powerful tool for practitioners. It has been observed that muscle volume in children with spastic diplegia was strongly associated with isometric strength [25]. However, observations from the current study revealed mixed individual results with no change in the mean data. Our results were limited by the sample size and possibly the length of training needed to accrue significant improvements in whole body or segmental muscle mass. Encouraging preliminary evidence from others does suggest that chronic resistance training can stimulate hypertrophy. McNee et. al. (2009) had participants with CP complete lower leg resistance training for 10 weeks. Following training they observed that gastrocnemius volumes increased (14-17%) and those increases were maintained 3-months following training [19]. In addition, Williams et. al. (2013) utilized a unique method to stimulate muscle hypertrophy in children with CP receiving a botulinum neurotoxin intervention (BotN) to reduce muscle tone. The combination of BotN and strength training for 10-weeks significantly improved lower body strength and muscle volume to a greater extent than the BotN alone [20]. These results are promising that people with CP can increase muscle mass with strength training, and may suggest that training periods lasting at least 10-weeks are necessary to see increases in hypertrophy.

In summary, we utilized a unique whole body progressive resistance training program that improved upper and lower body muscular strength, but did not increase whole body or segmented muscle mass. Following our preliminary study we have concluded that future investigations should include longer training periods lasting a minimum of 10-weeks and a larger sample size that may be necessary to determine the effects of chronic strength training on muscle hypertrophy in those with CP.

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References

[1] Bax M., Goldstein M., Rosenbaum P., Leviton A., Paneth N., Dan B., Jacobsson B., Damiano D. Proposed definition and classification of cerebral palsy. Developmental Medicine & Child Neurology, April 2005; 47(8): 571-576.

[2] Reddihough D.S., Collins K.J. The epidemiology and causes of cerebral palsy. Australian Journal of Physiotherapy, 2003; 49(1): 7-12.

[3] Keawutan P., Bell K.L., Oftedal S., Ware R.S., Stevenson R.D., Davies P.S.W., Boyd R.N. Longitudinal physical activity and sedentary behavior in preschool-aged children with cerebral palsy across all functions. Developmental Medicine and Child Neurology, August 2017; 58(8): 852-857.

[4] Waltersson L., Rodby-Bousquet E. Physical activity in adolescents and youth with cerebral palsy. Biomed Research International, 2018; 2018: 1-4.

[5] Veschuren O., Ketelaar M., Takken T., Helders P.J.M., Gorter J.W. Exercise programs for children with cerebral palsy: A systemic review of the literature. American Journal of Physical Medicine and Rehabilitation, 2007; 86(12): 1-14.

[6] Taylor N.F., Dodd K.J., Baker R.J., Wiloughby K., Thomason P., Graham H.K. Progressive resistance training and mobility-related function in young people with cerebral palsy: a randomized controlled study. Developmental Medicine and Child Neurology, 2013; 55(9): 806-812.

[7] Bania T.A., Dodd K.J., Baker R.J., Graham H.K., Taylor N.F. The effects of progressive resistance training on daily physical activity in young people with cerebral palsy: a randomized controlled trial. Disability and Rehabilitation, 2015; 38(7): 620-626.

[8] Unger M., Faure M., Frieg A. Strength training in adolescent learners with cerebral palsy: a randomized controlled trial. Clinical Rehabilitation, 2006; 20(6): 469-477.

[9] Taylor N.F., Dodd K.J., Larkin H. Adults with cerebral palsy benefit from participating in a strength programme at a community gymnasium. Disability and Rehabilitation, 2004; 26(19): 1128-1134.

[10] Dodd K.J., Taylor N.F., Graham H.K. A randomized clinical trial of strength training in young people with cerebral palsy. Developmental Medicine and Child Neurology, 2003; 45(10): 652-657.

[11] Darrah J., Wessel J., Nearingburg P., O'Connor M. Evaluation of a community fitness program for adolescents with cerebral palsy. Pediatric Physical Therapy, 1999; 11(1): 18-23.

[12] McCubbin J.A., Shasby G.B. Effects of isokinetic exercise on adolescents with cerebral palsy. Physical Activity Quarterly, 1985; 2: 56-64.

[13] Andersson C., Grooten W., Hellstein M., Kaping K., Mattsson E. Adults with cerebral palsy: walking ability after progressive strength training. Developmental Medicine and Child Neurology, 2003; 45(4): 220-228.

[14] Damiano D.L., Abel M.F. Functional outcomes of strength training in spastic cerebral palsy. Archives of Physical Medicine and Rehabilitation, 1998; 79(2): 119-125.

[15] Morton J.F. The effects of progressive resistance training for children with cerebral palsy. Clinical Rehabilitation, 2005; 19(3): 283-289.

[16] Wiley M.E., Damiano D.L. Lower-extremity strength profiles in spastic cerebral palsy. Developmental Medicine and Child Neurology, 1998; 40(2): 100-107.

[17] Ross S.A., Engsberg J.R. Relation between spasticity and strength in individuals with spastic diplegic cerebral palsy. Developmental Medicine and Child Neurology, 2002; 44(3): 148-157.

[18] Rose J., McGill K.C. The motor unit in cerebral palsy. Developmental Medicine and Child Neurology, 1998; 40: 270-277.

[19] McNee A.E., Gough M., Morrissey M.C., Shortland A.P. Increases in muscle volume after plantarflexor strength training in children with spastic cerebral palsy. Developmental Medicine and Child Neurology, 2009; 51(6): 429-435.

[20] Williams S.A., Elliot C., Valentine J., Gubbay A., Shipman P., Reid S. Combining strength training and botulinum neurotoxin intervention in children with cerebral palsy: the impact on muscle morphology and strength. Disability and Rehabilitation, 2013; 35(7): 596-605.

[21] Verschuren O., Takken T., Ketelaar M., Gorter J.W., Helders P.J.M. Reliability and validity of data for two newly developed shuttle run tests in children with cerebral palsy. Physical Therapy, 2006; 86(8): 1107-1117.

[22] Dodd K.J., Taylor N.F., Damiano D.L. A systemic review of the effectiveness of strength training programs for people with cerebral palsy. Archives of Physical Medicine and Rehabilitation, 2002; 83(8): 1157-1164.

[23] Schoenfield B.J., Grgic J., Ogborn D., Krieger J.W. Strength and hypertrophy adaptations between low- vs. high-load resistance training: a systematic review and meta-analysis. The Journal of Strength and Conditioning Research, 2017; 31(12): 3508-3523.

[24] Scholtes V.A., Becher J.G., Comuth A., Dekkers

Scholtes V.A., Becher J.G., Comuth A., Dekkers H., Van Dijk L., Dallmeijer A.J. Effectiveness of functional progressive resistance exercise strength training on muscle strength and mobility in children with cerebral palsy: a randomized controlled trial. Developmental Medicine and Child Neurology, 2010; 52(6): 107-113.

[25] Reid S.L., Pitcher C.A., Williams S.A., Licari M.K., Valentine J.P., Shipman P.J., Elliot C.M. Does muscle size matter? The relationship between muscle size and strength in children with cerebral palsy. Disability and Rehabilitation, 2015; 37(7): 579-584.