ORIGINAL ARTICLE

Effects of a Community-Based Progressive Resistance Training Program on Muscle Performance and Physical Function in Adults With Down Syndrome: A Randomized Controlled Trial

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ABSTRACT. Shields N, Taylor NF, Dodd KY. Effects of a community-based progressive resistance training program on muscle performance and physical function in adults with Down syndrome: a randomized controlled trial. Arch Phys Med Rehabil 2008;89:1215-20.

Objective: To determine whether progressive resistance training improves muscle strength, muscle endurance, and physical function in adults with Down syndrome.

Design: Single-blind randomized controlled trial.

Setting: General community.

Participants: Adults (N=20) with Down syndrome (13 men, 7 women; mean age, 26.8±7.8y) were randomly assigned through a concealed allocation block randomized method to either an intervention group (n=9) or a control group (n=11).

Intervention: The intervention was a supervised, group progressive resistance training program, consisting of 6 exercises using weight machines performed twice a week for 10 weeks. Participants completed 2 to 3 sets of between 10 to 12 repetitions of each exercise until they reached fatigue. The control group continued with their usual activities.

Main Outcome Measures: The outcomes measured by blinded assessors were muscle strength (1-repetition maximum [1-RM]), muscle endurance (number of repetitions at 50% of 1-RM) for chest press and leg press, timed stairs test, and the grocery shelving task.

Results: The intervention group showed significant improvement in upper-limb muscle endurance compared with the control group (mean difference in the number of repetitions of the chest press at 50% of 1-RM was 16.7, 95% confidence interval, [CI] 7.1–26.2); and a trend toward an improvement in upper-limb muscle strength (mean difference in chest press 1-RM, 8.6kg; 95% CI, −1.3 to 18.5kg) and in upper-limb function (mean difference in grocery shelving task, −20.3s; 95% CI, −45.7 to 5.2s). There were no significant differences between the groups for lower-limb muscle performance or physical function measures. No major adverse events for the intervention were noted.

Conclusions: Progressive resistance training is a safe and feasible fitness option that can improve upper-limb muscle endurance in adults with Down syndrome (ACTR identifier ACTRN 012606000515594.)

Key Words: Down syndrome; Exercise; Randomized controlled trial; Rehabilitation.

PEOPLE WITH DS HAVE REDUCED muscle strength and muscular endurance compared with their peers without disability and also compared with their peers with an intellectual disability but without DS.[1-3] Muscle weakness is associated with decreased cardiovascular fitness[4] and an increased incidence of osteoporosis in people with DS.[5] It can also impact the ability of people with DS to perform everyday activities, such as walking, maintaining balance while standing, and rising from a chair.[6] Further, because their workplace activities typically emphasize physical rather than cognitive skills, decreased strength can negatively impact the vocational and social development of adults with DS in the workforce.[7,8]

People with a range of disabilities have the capacity to improve muscle strength with progressive resistance training.[9,10] However, only 3 trials are known to have investigated the effects of this type of training program in people with DS.[11-13] Two of these trials included progressive resistance training[11,12] and 1 study used a combined strength training and aerobic program.[13] Each of these trials found improved upper-[11-13] and lower-limb muscle strength with training[12,13] but none of the trials reported the effects of the programs on muscle endurance or functional activities. These trials were also limited because none employed blinded assessors to collect the data and 2 studies[11,12] did not include a control group in their design. Because no RCT has been conducted investigating the effectiveness of a stand-alone progressive resistance training program, it is not known to what extent the reported effects of progressive resistance training in people with DS are due to the strength training intervention rather than due to series effects.

The aim of this trial therefore was to determine the effects of a community gymnasium-based progressive resistance training program on adults with DS. The specific objectives were to conduct an RCT to determine if a progressive resistance training program for adults with DS can lead to increased muscle strength and endurance, and, to improved physical function in this population. It was hypothesized that the adults with DS in the strength training program would have greater improvement in muscle strength, muscle endurance, and improved physical function compared with the control group.

List of Abbreviations

ACSM	American College of Sports Medicine
CI	confidence interval
DS	Down syndrome
1-RM	1 repetition maximum
RCT	randomized controlled trial

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METHODS

Research Design

We conducted a repeated-measures RCT. Adults with DS were randomly allocated to either an intervention group that received 10 weeks of progressive resistance training or a control group that continued with their usual activities. Both groups were assessed at baseline and after the intervention phase of the study. The trial received ethics approval from the university ethics committee, and all participants and their carers gave written informed consent to take part in the trial.

Participants

We recruited adults with DS through 2 disability agencies (1 rural, 1 metropolitan) that provide supported employment and day activity programs for adults with intellectual disabilities. The agencies mailed a flyer promoting the trial to a total of 46 families and those who were interested in taking part contacted the researchers directly. Participants were included if they were aged 18 years or more, had the ability to follow simple verbal instructions in English, and were fit and well enough to participate in a progressive resistance training program. The latter was determined by asking the carer of each participant to complete a copy of the 7-item Physical Activity Readiness Questionnaire.[14] The level of intellectual disability of each of the participants (described as mild, moderate, or severe as perceived by their parent or carer) was also documented. The exclusion criterion was participation in a strength training program in the 6 months prior to the start of the study. Based on a power analysis of the training effects on lower-limb muscle strength found in people with DS in a previous study ($d=1.26$),[12] it was calculated that 10 subjects would be needed in each group to obtain power of 80%.

Randomization

Participants were randomly allocated to either the intervention or control group using a concealed allocation, block randomization method that ensured approximately equal numbers in each group with the relatively small sample.[15] We considered participants in blocks of 4, with 6 ways or permutations in which to get 2 intervention and 2 control participants in each block. The order of the blocks was generated from a random number table and assignments sealed in sequentially numbered opaque envelopes. Only after the recruiter determined if a person was eligible for the study and they had agreed to participate was random assignment made. Participants were assigned to their allocation by a physiotherapist not involved in the study after the baseline measures were taken.

Intervention

Participants in the intervention group completed a 10-week progressive resistance training program. Training was completed twice a week at a community gymnasium and followed the principles of progressive resistance training as recommended by the ACSM.[16] The program consisted of 6 exercises using weight machines: 3 for the upper limbs (shoulder press, seated chest press, seated row) and 3 for the lower limbs (seated leg press, knee extension, seated calf raise). These exercises formed the basis of the training program but could be modified to suit the needs of the individual. For example, if a participant found it difficult to do the seated calf raise exercise, the trainer could try modifying the exercise as a standing calf raise exercise. Participants completed 2 to 3 sets of between 10 to 12 repetitions of each exercise until they reached fatigue. A 2-minute rest period was given between each set to allow for recovery, and the resistance was increased when 2 sets of 12 repetitions of an exercise could be completed.[16] A log book for each participant that detailed each exercise, the weight lifted, the number of repetitions, and number of sets was filled at each session by the exercise trainer. Participants completed the program as a group, supervised by 2 accredited fitness trainers. Each trainer supervised the training of a subgroup of 2 to 3 participants. Exercising in a small subgroup allowed for a close level of supervision.

Participants in the control group continued with their typical daily activities, which included employment, leisure, and sporting activities, but did not include a progressive resistance training program. For ethical reasons, after the 10-week assessment, participants in the control group were invited to complete the strengthening program, but no further follow-up measurements were conducted.

Outcome Measurements

We assessed all participants at baseline (week 0) and immediately after the intervention period (week 10) at the recreation center where the intervention took place. The outcome measurements were taken by assessors who were blind to group allocation and who had no involvement in the recruitment, the randomization, or the training of participants. There were 2 assessors: 1 assessor completed the muscle performance tests and the second assessor completed the physical function tests. Assessors received training on how to administer the outcome measures.

Muscle performance was assessed using tests for maximal force generation (1-RM) and muscle endurance. Maximal muscle force generation was tested by establishing the amount of weight each participant could lift in a single seated chest press and seated leg press (1-RM). A single 1-RM chest press and leg press have been measured with high levels of retest reliability ($r>.89$) and no systematic change when measured over 3 weeks in adults with neurologic impairment.[17] Muscle endurance was measured by counting the number of repetitions that could be completed when the weight on the seated chest press and seated leg press was lowered to 50% of 1-RM. The baseline weight that was lifted was used for the 10-week measurement.[18] There is evidence of construct validity for this measure because hypothesized changes were detected in a group of adults with neurologic impairment.[17]

Physical function was measured using 2 outcomes measures; the timed stairs test and the grocery shelving task. For the timed up and down stairs test, participants stood at the bottom of a flight of stairs and were asked to ascend and descend the steps as quickly and as safely as possible. Participants were allowed to choose any method of traversing the stairs including alternating steps, running up the stairs, or skipping steps. There were 2 handrails available on the stairs and participants were allowed to use these. The participants were given the cues, ready and go, and the time taken to go up the stairs, turn around, come all the way down until both feet landed at the foot of the stairs was recorded in seconds using a stopwatch. The test was repeated twice with the fastest time used in the analysis.[19] The test has been measured reliably ($r=.89$) in a population of adults with multiple sclerosis.[20]

We used the grocery shelving task[21-23] to measure upper-body functional activity. For this test, participants were asked to stand up from a chair and carry 2 grocery bags to a bench 2m way. Each grocery bag contained 10 items; each item weighed 410g (total weight of each grocery bag, 4.1kg). The participants then took the items out of the bag and stacked them onto a shelf at shoulder height. Participants were asked to complete the task as quickly as possible and the time taken

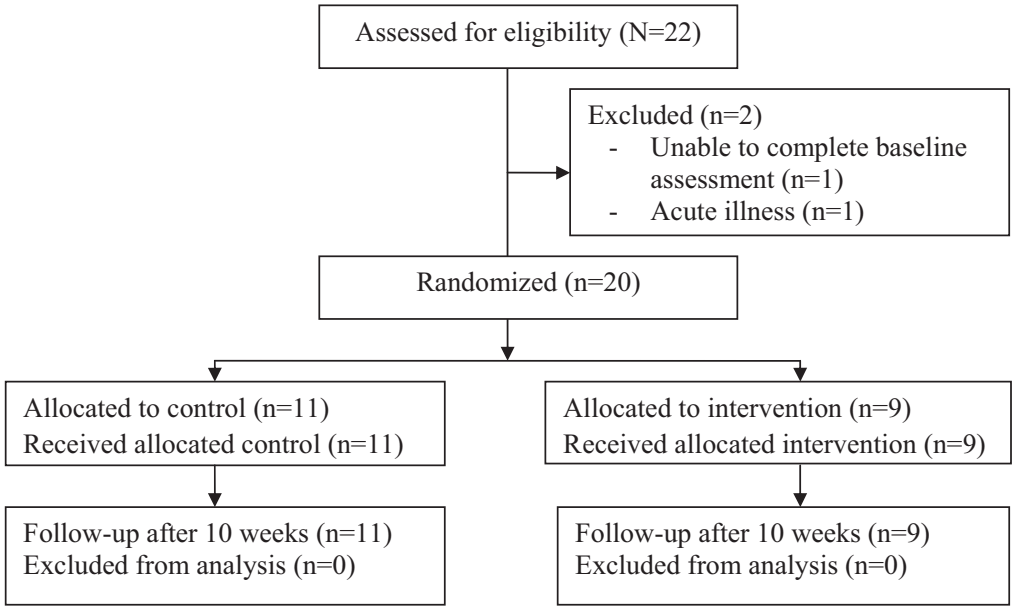

Fig 1. Number of participants at each stage of the trial (enrollment, allocation, follow-up, analysis).

to complete the test was measured. All the participants were given 1 practice trial at each assessment before they completed 2 timed tests, the average of which was used in the analysis. The grocery shelving task has shown high retest reliability (intraclass correlation coefficient, .98) when tested over 6 weeks in a group of adults with respiratory disability,[21] but has not previously been applied to adults with intellectual disability.

Adverse events that occurred during training (including minor events such as delayed onset muscle soreness) were systematically recorded by the fitness trainers on the participant's exercise log book. At the start and at the end of each exercise session the trainer asked each participant if they had experienced any injuries or any other problems.

Data Analysis

Data were analyzed using SPSS statistical software[a] to determine if there were any significant baseline demographic (sex, age, weight) differences between the intervention and control groups using the independent *t* test and Fisher exact probability test, as appropriate. Outcomes were analyzed using analysis of covariance on the change scores with the baseline measure of that variable used as the covariate.[24] Where baseline variables were significantly different, they too were entered as covariates. The mean difference within each group and the mean difference between the groups and the 95% CIs of the mean differences were also calculated. Effect sizes and 95% CIs were also calculated for the change scores. To avoid bias and to maximize the randomization process, we used intention-to-treat analysis. Where data were missing, the carry forward technique was used, which assumes that missing data remain constant.[25]

RESULTS

Flow of the Participants Through the Trial

Twenty adults (13 men, 7 women) with DS volunteered to take part in the study. Participants ranged in age from 20 to 49 years, with a mean age ± SD of 26.8±7.8 years. The mean height of the group was 155.1±9.3cm (range, 134–169cm) and the mean weight was 68.9±13.3kg (range, 51.8–102.0kg). Nine participants were randomly allocated to the intervention group and 11 participants to the control group and their progress through the trial is shown in figure 1. The demographic details of the participants for each group are displayed in table 1 and as the table shows, the only significant difference at baseline was that the intervention group weighed more than the control group. Eight of the 20 participants were employed at least 1 day a week performing manual type work that required them to pack boxes of confectionery, sorting and cutting clothing, and assembling automotive parts.

Compliance With the Trial Method

There were no withdrawals from the study. Participants attended 167 (92.8%) of 180 scheduled training sessions. Missed sessions of training were due to illness unrelated to the training program or to vacation time. None of the sessions were missed due to soreness or injury due to the training program.

Table 1: Demographic Data for Intervention and Control Groups

Characteristic	Intervention (n=9)	Control (n=11)	Statistical Test	*P*
Mean age ± SD (y)	25.8±5.4	27.6±9.5	−0.52	0.61
Sex (male/female)	7/2	6/5	NA	0.37
Mean height ± SD (cm)	158.8±7.12	152.0±10.0	1.7	0.11
Mean weight ± SD (kg)	78.4±13.5	61.2±6.7	3.5	0.01
Mean BMI ± SD (kg/m^2)*	31.2±6.0	26.8±5.2	1.8	0.09
Level of perceived ID			NA	
Mild	2	2		0.63
Moderate or severe	7	9		
Living arrangements				
With parents	8	8	NA	0.38
SSA or independent	1	3		
Employed	4	4	NA	1.00

Abbreviations: BMI, body mass index; ID, intellectual disability; NA, not applicable; SSA, shared supported accommodation.
*Referent BMI is 18.5–24.9kg/m^2, overweight is 25–29.9kg/m^2, obese is ≥30kg/m^2.[30]

No serious adverse events for the intervention were noted. Four participants complained of mild muscle soreness as a result of training, most reports occurring in the early weeks of training, and recovered spontaneously. No other adverse events were recorded.

Over the course of the training program, the intervention group increased the amount of weight lifted during training in the 6 exercises by at least 90% of the initial training resistance. To assess the success of assessor masking, assessors were asked to guess whether a participant had been allocated to the intervention or the control group. Assessors correctly guessed group allocation 56.8% of the time (Fisher exact test, $P=.74$).

Effect of the Intervention

The intervention group had a statistically significant improvement in upper-limb muscle endurance compared with the control group (mean difference in the number of repetitions of the chest press at 50% of 1-RM, 16.7; 95% CI, 7.1–26.2; $P<.01$). There were also trends toward improvement in upper-limb muscle strength (mean difference in chest press 1-RM, 8.6kg; 95% CI −1.3 to 18.5kg; $P=.08$) and upper-limb function (mean difference in time to complete the grocery shelving task, −20.3s; 95% CI, −45.7 to 5.2s; $P=.11$) that favored the intervention group (table 2). There were no significant differences between the groups for lower-limb muscle strength, lower-limb muscle endurance, or lower-limb physical function (see table 2).

DISCUSSION

Our main finding in this study was that upper-limb muscle performance improved in adults with DS after a 10-week progressive resistance exercise program. There was a significant increase in chest press endurance and also a trend toward an increase in upper-limb strength as measured by a 1-RM chest press and upper-limb functional activity as measured by a grocery shelving task. The effect sizes observed were moderate to large (.76–.90) and the changes in upper-limb strength carried over to trends to changes in upper-limb physical function tasks suggests these results may be clinically significant. The change in upper-limb endurance may be relevant in these adults, whose employment involves manual work of the upper limbs.

The progressive resistance exercise program implemented for this study was feasible for adults with DS. It might be expected that adults with DS have difficulty taking part in or being motivated to continue with a progressive resistance exercise program. The majority of participants in this trial had a moderate level of intellectual disability as determined by their parents and carers, yet they were all capable of taking part in the program and experienced benefits from doing so despite their intellectual disability. Compliance with the program was excellent, with participants attending 92% of all training sessions. There were also no withdrawals from the study, indicating that a strength training program was an acceptable form of exercise to the participants. The high attendance rates were likely influenced by the support provided by the day programs attended by the participants. This support included providing transport to and from the community gymnasium and this might be an important factor to consider when setting up future programs.

Another positive finding was that the training program appeared to be a safe intervention for people with DS. No major adverse events were reported by the participants, their families, or the fitness trainers involved in the program. Some participants complained of muscle soreness during the initial weeks

Table 2: Mean Score, Mean Difference Within Groups, and Mean (95% CI) Difference Between Groups for All Outcomes for the Intervention Group and the Control Group

Outcome	Score				Difference Within Groups		Difference Between Groups		
	Baseline (week 0)		Postintervention (week 10)		Week 10–Week 0		Week 10–Week 0*	*P**	Effect Size (95% CI)
	Int	Con	Int	Con	Int	Con	Int–Con (95% CI)		
Chest press 1-RM (kg)	35.9±15.4	28.0±10.2	44.9±15.2	31.6±13.3	9.0±8.2	3.6±7.1	8.6 (−1.3 to 18.5)	.08	0.68 (−0.20 to 1.59)
Leg press 1-RM (kg)	80.8±25.9	70.8±20.0	96.2±31.6	82.2±19.7	15.4±20.7	11.4±12.0	−1.3 (−22.5 to 20.0)	.90	0.23 (−0.65 to 1.12)
Chest press endurance (no. of repetitions)	15.0±4.7	19.0±8.1	25.9±8.3	17.5±9.5	10.9±8.6	−1.6±8.0	16.7 (7.1 to 26.2)	.002	1.51 (0.46 to 2.44)
Leg press endurance (no. of repetitions)	44.1±25.9	44.5±21.3	46.8±37.1	49.4±27.6	2.7±47.4	4.9±21.2	16.5 (−23.1 to 56.0)	.39	−0.06 (−0.94 to 0.82)
Timed up and down stairs test (s)	16.6±5.2	20.2±6.3	14.4±3.4	18.7±6.5	−2.1±2.7	−1.5±4.3	−3.4 (−7.7 to 1.0)	.12	0.16 (−0.73 to 1.04)
Grocery shelving task (s)	85.1±49.1	122.8±84.0	67.5±33.4	110.7±66.4	−17.6±29.0	−12.0±23.2	−20.3 (−45.7 to 5.2)	.11	0.22 (−0.68 to 1.09)

NOTE. Values are mean ± SD or as otherwise indicated.
Abbreviations: Con, control group; Int, intervention group.
*Derived from analysis of covariance with dependent variable on admission and baseline weight as covariates.

of training, but this was to be expected in a group of people who had not previously participated in a strength training program. This finding is consistent with conclusions that strength training appears to be a relatively safe intervention for people with a broad range of health conditions[10]; and may help to counter attitudes that health concerns are a reason why adults with DS should not take part in physical activities.[26]

No changes in the lower-limb muscle performance of adults with DS were found in this study. There might be a number of reasons for this. It should be considered whether the training program was of sufficient intensity, frequency, and duration. The training program completed by the participants adhered to the ACSM[16] guidelines for progressive resistance exercise; that is, a small number of repetitions could be performed before fatigue, sufficient rest was allowed for recovery between exercises and the amount of resistance was progressed as the ability of the participants increased. During the trial participants were closely supervised to ensure that this was the case and the fitness trainers indicated in the logbooks they completed that the program was progressed as it proceeded. Therefore, it would not seem that the results were due to a problem with the training program.

It is possible that previous trials may have overestimated the size of the treatment effect of strength training for adults with DS. Preliminary evidence from a systematic review[9] suggested that programs designed to improve strength in adults with DS had large positive effects. However, none of the trials included in this review were RCTs; indeed these trials were repeated measures designs with no controlled baseline or control group data, and may have overestimated the benefits from strength training. Strength training may therefore have positive effects in adults with DS but the size of the effect may be smaller than the previous literature suggests.

It is also possible that the adults with DS in the current study did not have the same potential for improving their lower-limb muscle performance as for their upper-limb muscle performance. For example, upper-limb endurance at baseline was much lower (mean, 15 and 19 repetitions for the intervention and control group, respectively) than lower-limb endurance at baseline (means of 44.1 and 44.5 repetitions for the intervention and control group, respectively) suggesting there was much greater capacity for improvement in the upper limbs. This difference between the upper and lower limbs might be explained by adults with DS routinely using the antigravity support muscles to maintain posture during activities of daily living, such as walking and stair climbing, whereas they may use their upper-limb muscles more infrequently.

Another reason for the lack of change in lower-limb muscle performance was that any true changes may have been obscured by measurement variability. However, standardized procedures were used for testing that have previously been shown to be reliable in other adult populations with disability, and these procedures were able to detect changes in upper-limb muscle performance in the current study.

A training program of longer duration and higher frequency might have resulted in changes in the other outcome measures employed in this study because researchers have reported greater gains in strength from training programs involving longer durations and frequency.[27-29] The relatively short duration of the program (10wk) may not be enough to produce large changes in lower-limb strength. A program of longer duration might be more effective. Because the majority of the participants had a moderate level of intellectual disability, some took several weeks to adapt to the program and to learn how to use the weight equipment, so that overall the number of weeks they were working effectively was less than 10 weeks. Increasing the frequency of the program from twice a week to 3 times a week might also change the outcome because previous research studies trained adults with DS 3 times a week and reported larger positive effects.[11,12]

The main strength of this trial was that it was an RCT that assessed the effects of a progressive resistance exercise program that conformed to the training guidelines of the ACSM for adults with DS. It adds to an area of research where to date only 3 previous studies are known to have investigated if strength training programs are beneficial for adults with DS[11-13] and only 2 of these studies have examined stand-alone progressive resistance training programs. A further strength of this trial was that it was an inclusive community-based exercise program and this is important because people with DS often have restricted opportunities to participate in exercise programs taking place in a community setting.[6] The use of a group-based program where adults with DS exercised together was important because it made exercising into a more social activity,[26] and it is more cost effective and time efficient than individual training. Strength training performed in a community setting, as in this trial, may be a feasible recreation option for adults with DS.

Study Limitations

This trial was limited by the relatively small sample size of 20 participants, which required the effects of the intervention to be large in order to detect any changes as a result of the strength training program. The duration and frequency of the program may also have been too short to result in large changes in muscle performance and functional activities. Future trials should investigate if longer duration training programs are indeed more beneficial.

CONCLUSIONS

Progressive resistance training performed in a community gymnasium is a feasible and safe fitness option for people with DS that can lead to improvements in upper-limb muscle performance. Longer training programs may be required to improve leg strength and activity.

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