A student-led progressive resistance training program increases lower limb muscle strength in adolescents with Down syndrome: a randomised controlled trial

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Question: Does progressive resistance training improve muscle strength and physical function in adolescents with Down syndrome? **Design**: Randomised controlled trial with concealed allocation, assessor blinding, and intention-to-treat analysis. **Participants**: 23 adolescents with Down syndrome (17 boys, 6 girls; mean age 15.6 ± 1.6 years) were randomly assigned to either an experimental group (n = 11) or a control group (n = 12). **Intervention**: The intervention was a student-led progressive resistance training program, comprising 6 exercises using weight machines performed twice a week for 10 weeks. Participants completed 3 sets of 12 repetitions of each exercise or until they reached fatigue. The intervention took place in a community gymnasium. The control group continued with their usual activities. **Outcome measures**: The outcomes measured at baseline and immediately after the intervention phase were muscle strength (1 repetition maximum), a timed stairs test, and the grocery shelving task. **Results**: The experimental group attended 90% of their scheduled sessions. They demonstrated improvement in lower limb muscle strength compared to the control group (MD 36 kg, 95% CI 15 to 58). There were no significant differences between the groups for upper limb muscle strength or physical function measures. No major adverse events were recorded. **Conclusion**: Progressive resistance training is a feasible and safe exercise option that can improve lower limb muscle strength in adolescents with Down syndrome. **Trial registration**: ACTRN12608000261314. **[Shields N, Taylor NF (2010) A student-led progressive resistance training program increases lower limb muscle strength in adolescents with Down syndrome: a randomised controlled trial. *Journal of Physiotherapy* 56: 187–193]**

Key words: Exercise, Randomized controlled trial, Resistance training, Down syndrome

Introduction

Good muscle strength is particularly important for young people with Down syndrome because their workplace activities typically emphasise physical rather than cognitive skills (Shields et al 2008). The physical component of work tasks can be a problem because of muscle weakness. Muscle strength in the upper (Pitetti et al 1992) and lower limbs (Croce et al 1996) is up to 50% less in people with Down syndrome compared to their peers with typical development and also compared to their peers with an intellectual disability but without Down syndrome. Muscle weakness can also impact their ability to perform everyday activities, including walking (Carmeli et al 2002). Improvement in strength has been associated with positive changes in functional activities in adults with Down syndrome (Carmeli et al 2002) and in work-related skills in people with intellectual disability (etts et al 1995).

People with intellectual disability have the capacity to improve their muscle strength with progressive resistance training (Shields and Dodd 2004). In progressive resistance training, high loads are lifted for a low number of repetitions before muscular fatigue, and the load is progressed as the person gets stronger (American College of Sports Medicine 2009). Only four trials have investigated the effects of progressive resistance training in people with Down syndrome (Davis and Sinning 1987, Rimmer et al 2004, Shields et al 2008, Weber and French 1988). These studies found improved upper (Davis and Sinning 1987, Rimmer et al 2004, Weber and French 1988) and lower limb muscle strength with training (Rimmer et al 2004, Weber and French 1988). Only one of these studies investigated the effect of progressive resistance training in adolescents with Down syndrome (Weber and French 1988), but it did not include a control group in its design, the assessors were not blind to group allocation, and it did not report the effects of the training on functional activities. Therefore, because of potential biases in research design, it is not known to what extent the reported effects are due to the intervention, or if any improvements in muscle strength carried over into an improved ability to complete functional tasks.

Adolescence is a strategic time to implement an exercise program as establishing good exercise habits early in life is an important predictor of continued healthy activity patterns in adulthood (Telama et al 2005). Children with Down syndrome become less active during adolescence (Shields et al 2009). It is especially important for young people with Down syndrome to exercise because they have lower cardiovascular fitness than their peers without disability (Baynard et al 2008). The causes of their lower fitness are unclear but are due in part to their low peak heart rate (approximately 30% below expected) and may be due to their reduced physical activity levels, ventilatory difficulties, and reduced muscle strength (Khalili and Elkins 2009;

Baynard et al 2008). People with Down syndrome are also predisposed to a higher incidence of cardiovascular disease (Hill et al 2003), diabetes (Hermon et al 2001), osteoporosis and obesity, and so are more susceptible to a premature and significant decline in function as they age (Rimmer et al 2004). It is also a pertinent time because future employment may be dependent on their physical ability.

Adolescents with Down syndrome should be encouraged to engage in exercise as they transition to adulthood. However, they face significant barriers to participation in exercise including a need for someone to exercise with (Heller et al 2002) and a need for suitable programs (Menear 2007). Facilitators of exercise for this group include: the need for close supervision, motivational support, and the need to ensure they exercise at the correct intensity (Shields et al 2008), and to provide for social interaction (Menear 2007). Exercising at a gym is a socially acceptable activity for typically developing adolescents, and might be a reasonable recreation option for adolescents with Down syndrome. The aim of this trial therefore, was to determine the effects of a student-led community-based progressive resistance training program for adolescents with Down syndrome. A student-led program provides the supervision and social interaction adolescents with Down syndrome need to exercise.

The research questions were:

1. Does a progressive resistance training program lead to increased muscle strength in adolescents with Down syndrome?
2. Does it lead to improved physical function in these adolescents?

Method

Design

We conducted a randomised controlled trial. Adolescents with Down syndrome were recruited for the trial through a community support group for people with Down syndrome and their families. A flyer promoting the trial was mailed to members as part of the support group's usual mail out and families were asked to contact the researchers if interested.

Participants were randomly allocated to the experimental or control group using a concealed method. Participants were randomised in blocks of four, generated from a random numbers table with assignments sealed in sequentially numbered, opaque envelopes. Assignment was made after the recruiter had determined eligibility for the study and their parents had consented to the adolescent's participation. Group allocation was prepared and performed by a researcher not involved in recruitment or assessment by opening the next envelope in the sequence.

The experimental group received 10 weeks of progressive resistance training and the control group continued with their usual activities. All participants completed assessments of muscle strength and upper and lower limb physical function at baseline (week 0) and immediately after the intervention phase of the study (week 11). The assessments were completed by an assessor who was blind to group allocation and who was not involved in any other aspect of the trial.

Participants

Participants were included if they were aged 13–18 years, were able to follow simple verbal instructions in English, and were fit and well enough to participate in the training program. The last inclusion criterion was ascertained by asking parents to complete the 7-item Physical Activity Readiness questionnaire on behalf of their child. The level of intellectual disability of each participant (described as mild, moderate, or severe as perceived by their parent) was documented. Parent perceptions were used to give a general indication of the level of disability of their child and because of concerns about formal intelligence testing in this population (American Association on Intellectual and Developmental Disabilities 2010). Participants were excluded if they had participated in a progressive resistance training program in the 6 months prior to the trial.

We adopted a 40% increase in 1RM leg press as the minimum clinically important difference based on a previous trial by Rimmer et al (2004). The standard deviation in 1RM leg press in a similar population was 41.5 kg (Rimmer et al 2004). From this, we calculated that to maintain power of 80% with a significance level of 0.05, we required 11 participants per group to complete the study.

Intervention

The experimental group completed progressive resistance training twice a week for 10 weeks at a community gymnasium located close to where each adolescent with Down syndrome lived. A 10-week program was selected as it fits in with the typical school term and therefore could be timetabled around the weekly schedule of the families of the adolescents. The training program (including the duration and frequency of the program) was designed according to the recommendations of the American College of Sports Medicine (American College of Sports Medicine 2009). The participants performed six exercises using weight machines; three for the upper limbs (lat pull-down, seated chest press, seated row) and three for the lower limbs (seated leg press, knee extension, calf raise). These exercises were chosen because they would strengthen the major multi-joint muscles of the upper and lower limbs. The exercises were conducted on pin-loaded weight machines as they were considered safer for novice participants than free weights as there was less chance of a weight being dropped on a body part and causing injury. These exercises could be modified to suit the needs of the individual, or the availability of training equipment at a particular gymnasium. All but very minor modifications were completed by the student mentors in conjunction with the researchers. For example, if a participant found it difficult to do the standing calf raise exercise, the exercise could be modified to a seated calf raise exercise. Participants performed up to 3 sets of 12 repetitions of each exercise, or until fatigue. A 2-minute rest was taken between each set to allow for recovery, and the resistance was increased when 3 sets of 12 repetitions of an exercise could be completed (American College of Sports Medicine 2009).

The progressive resistance training program was led by student mentors recruited from the physiotherapy student body at the university. Provision was made for the students to include the training experience as part of their clinical experience portfolio. To ensure consistency, the student mentors received training on the program content, the exercise equipment, program progression, and motivational strategies. Each student mentor was contacted by a researcher every three weeks during training to monitor progress and help solve any problems. The adolescents with Down syndrome were matched with a student mentor based on the metropolitan suburb where they lived and, in some cases where parents requested this, based on gender. The student mentors also completed a progressive resistance training program, completing their exercise set while the adolescent with Down syndrome was taking their 2-minute rest between sets. The mentors were responsible for completing a log book for the adolescent with Down syndrome detailing each exercise performed, the weight lifted, the number of repetitions, and number of sets.

The control group participants continued with their usual activities, which may have included leisure and sporting activities but did not include a progressive resistance training program. After the trial was completed, these participants were invited to complete the same program with a student mentor, but no further assessments were conducted.

Outcome measures

Primary outcome: Muscle strength was assessed using 1 repetition maximum (1RM) force generation tests. These tests established the amount of weight each participant could lift in a single seated chest press and seated leg press respectively. Single 1RM chest press and leg press tests have high levels of retest reliability (r ® 0.89) and demonstrated no systematic change when measured over 3 weeks in adults with neurologic impairment (Taylor et al 2004). Single 1RM chest press and leg press tests were used as representative measures of upper and lower limb strength, respectively, as they involve the major muscle groups exercising over multiple joints.

Secondary outcome: Lower-limb physical function was measured using the Timed Up and Down Stairs test (aino et al 2004). This test was chosen because it is a challenging test of mobility that would be expected to be related to an improved ability to generate muscle force. It has also been implemented previously as an outcome measure in a population of people with Down syndrome (Shields et al 2008). Participants were asked to ascend, turn, and descend a flight of stairs as quickly as possible. They could choose any method of traversing the stairs including alternating steps, running up the stairs, or using handrails for support. The time taken to complete the task was recorded in seconds using a stopwatch. The test was repeated twice and the fastest time was used in the analysis. Secondary analysis of data from our laboratory has demonstrated moderate retest reliability of the Timed Up and Down Stairs test in adults with Down syndrome ($ICC_{3,1}$ = 0.74).

Upper-limb physical function was measured using the Grocery Shelving Task (Hill et al 2004). Participants started from a seated position 2m from a bench. They were asked to stand up and carry 2 grocery bags, each containing 10 items weighing 410 g (total weight of each bag was 4.1 kg), to the bench. The participants then took the items out of the bag and stacked them onto a shelf at shoulder height. The participants completed the task as fast as possible and the time taken was recorded. Participants were given a practice trial before they completed two timed tests, the average of which was used in the analysis. Secondary analysis of data from our laboratory has demonstrated moderate retest reliability of the Grocery Shelving Task in adults with Down syndrome ($ICC_{3,1}$ = 0.76).

Any adverse events that occurred during training (including minor events such as delayed onset muscle soreness) were recorded by the student mentor in the participant's exercise log book. At the beginning and end of each session the student mentor asked the participant if they had experienced any injuries or other problems.

Table 1. Baseline characteristics of participants.

Characteristic	Randomised (n = 23)	
	Exp (n = 11)	Con (n = 12)
Age *(yr)*, mean (SD)	15.9 (1.5)	15.3 (1.7)
Gender, n males (%)	8 (73)	9 (75)
Height *(cm)*, mean (SD)	159 (11)	156 (7)
Weight *(kg)*, mean (SD)	63 (6)	58 (7)
BMI	25.5 (4.4)	24.0 (3.2)
Level of perceived ID, n (%)		
Mild	1 (9)	5 (42)
Moderate	10 (91)	5 (42)
Severe	0 (0)	2 (16)
School or program, n (%)		
Mainstream	0 (0)	3 (25)
Specialist	11 (100)	9 (75)

Exp = experimental group, Con = control group, ID = intellectual disability, BMI = body mass index

Data analysis

Intention to treat analysis was performed and outcomes were analysed using ANCOVA with the baseline measure of each variable used as the covariate (Vickers 2005). Where data were missing, the carry-forward technique was used, which assumes that missing data remained constant (Hollis and Campbell 1999). The mean difference within each group and between the groups and their 95% CI were calculated. Standardised mean differences (SMD) (otherwise known as effect sizes) were also calculated. SMDs were calculated by subtracting the mean of the control group from the mean of the experimental group and dividing by the pooled standard deviation. The SMDs were interpreted as follows: less than 0.2 was considered small, between 0.2 and 0.5 was considered moderate, and greater than 0.8 was considered large (Cohen 1977).

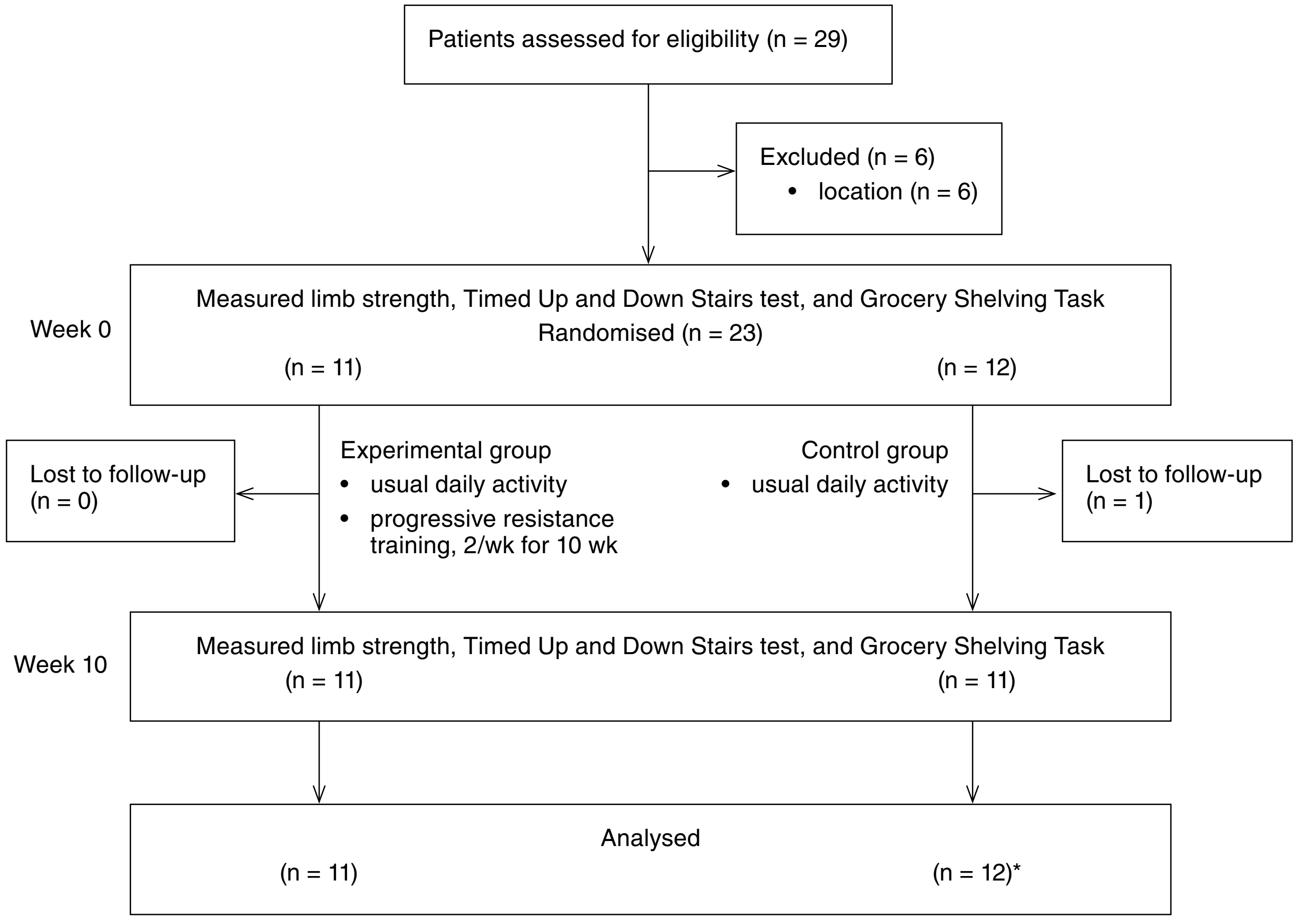
Results

Flow of the participants through the trial

Twenty-three adolescents (17 boys, 6 girls) with Down syndrome participated in the trial (Table 1). The participants had a mean age of 15.6 years (SD 1.6) and a mean body mass index of 24.7 kg/m^2 (SD 3.8, range 19.8 to 35.0). Eleven participants were randomly allocated to the experimental group and 12 participants to the control group. There were no apparent differences at baseline between the groups for most of the demographic factors or outcome measures (Tables 1 and 2). However, the proportion of adolescents with moderate/severe intellectual disability appeared to be greater in the experimental group compared with the control group.

Compliance with the trial method

Participants attended 90% (198/220) of the scheduled training sessions. No serious adverse events were recorded.



* The 12th participant in the control group was included in the analysis by the carry-forward approach

Figure 1. Design and flow of participants through the trial.

Missed sessions were due to illness or vacation time. None of the sessions was missed due to soreness, injury, or illness as a result of the training program. Four participants complained of mild muscle soreness during training, mostly during the early weeks of the program and all recovered spontaneously. Three participants complained of sore hands as a result of using the weight equipment; one participant resolved this by wearing gloves during training. Over the course of the training program, the experimental group progressed the amount of resistance lifted for each of the prescribed exercises by at least 95% of the initial training resistance. One participant in the control group was unavailable for reassessment but this participant was included in the intention to treat analysis via the carry-forward approach (Fig. 1).

Effect of the intervention

The average baseline 1RM for leg press was 88 kg, approximately 15% less than values for adolescents with typical development (Christou et al 2006). The experimental group increased lower limb muscle strength compared to the control group (MD 36 kg, 95% CI 15 to 58, SMD 0.7). The lower limb strength increase represented a 42% increase in baseline strength in the experimental group compared to the control group. There were no significant differences between the groups for upper limb muscle strength or upper and lower limb physical function. Group data are presented in Table 2 and individual data in Table 3 (see eAddenda for Table 3). The SMD for the 1RM chest press was 0.6, for the timed stairs test was 0.5, and for the Grocery Shelving Task was 0.3, which represented moderate effects.

No major adverse events were reported. Although five participants complained of muscle soreness during the initial weeks of training, this did not preclude them from training. The reported symptoms were mild and were to be expected in a group of novice trainees completing moderate to high intensity training.

Discussion

Several of the study's findings indicate that progressive resistance training was feasible and safe for adolescents with Down syndrome when facilitated by a student mentor. Adherence to the program was excellent, adverse events were minimal, the reasons for missed sessions were unrelated to the intervention, and the only participant lost to follow-up was allocated to the control group. These data suggest progressive resistance training was an acceptable form of exercise to the participants, a finding consistent with previous literature concluding that this type of training is safe for people with a range of health conditions and disabilities (Taylor et al 2005). This is an important finding, as some people with intellectual disability and their carers are apprehensive about taking part in exercise and believe they should not engage in exercise (Heller et al 2004). Our results and future studies should alleviate this concern and may encourage people with Down syndrome to become more active. Given that people with Down syndrome are

Table 2. Mean (SD) score, mean (SD) difference within groups, and mean (95%CI) difference between groups for all outcomes for the experimental group and the control group.

Outcome	Score				Difference within groups		Difference between groups
	Baseline (week 0)		Post-intervention (week 10)		Week 10 minus Week 0		Week 10 minus Week 0* (95 % CI)
	Exp	Con	Exp	Con	Exp	Con	Exp-Con
Chest press 1RM *(kg)*	44 (18)	40 (9)	55 (24)	44 (12)	11 (15)	5 (8)	8 (–3 to 17)
Leg press 1RM *(kg)*	87 (46)	89 (44)	132 (50)	97 (43)	45 (31)	8 (17)	36 (15 to 58)
Timed Up and Down Stairs test *(sec)*	18 (8)	20 (9)	15 (6)	22 (18)	–3 (4)	3 (17)	–6 (–17 to 5)
Grocery Shelving Task *(sec)*	80 (38)	88 (38)	74 (31)	87 (48)	–6 (17)	–1 (25)	–6 (–25 to 13)

* = derived from ANCOVA with dependent variable at baseline as covariate. Con = control group, Exp = experimental group

at risk of the health consequences of inactivity (Hill et al 2003), it is necessary that we identify feasible exercise options for this group. These results suggest that progressive resistance training can be a safe, socially desirable, and feasible exercise and recreation option for adolescents with Down syndrome.

Our data show that progressive resistance training was effective in improving the strength of the major antigravity muscles of the lower limb (quadriceps and hip extensors) in adolescents with Down syndrome. The average percentage increase in muscle strength was 42%, which was clinically worthwhile and was similar to increases of 27–46% reported in other populations (O'Shea et al 2007, Dodd et al 2004). Although it cannot be concluded with 95% confidence that there was a change in upper limb strength, the SMD was similar in magnitude to what was observed for changes in lower limb muscle strength. These findings are notable considering the relatively short duration of the program and the fact that the majority of the participants had moderate to severe intellectual disability. An increased ability to generate force in the major muscles of the lower limb may be important for adolescents with Down syndrome, whose vocational roles may be influenced by their physical capacity.

Although no corresponding changes in physical function were found, the observed SMDs for these variables (0.3 for the Grocery Shelving task and 0.5 for the timed stairs test) indicated a moderate observed effect size. Effect sizes of this magnitude are encouraging and are similar to those reported among adults with Down syndrome (Shields et al 2008). If these SMD results were confirmed on a larger sample, then it is possible progressive resistance training might have clinically significant effects on the physical functioning of adolescents with Down syndrome. The SMDs for the physical functional measures were smaller than for the muscle strength measures. This is expected as muscle strength is only one component required for these functional tasks; that is, there was less specificity of training for these functional tasks. Consistent with this, there are some data in people with Down syndrome to suggest that muscle strength is an important but not the only variable important in completing functional tasks (Cowley et al 2010).

An innovative aspect of this trial was that the progressive resistance training intervention was led by physiotherapy student-mentors. This feature provided the supervision and the social interaction needed to encourage the adolescents to exercise. Choosing physiotherapy students to act as mentors was advantageous as they had an understanding of the principles of exercise training, and were also close in age to the adolescents so that the social interaction between the pair was meaningful. An additional benefit was that the physiotherapy students had the opportunity to gain a unique experience of disability, something that they may not necessarily have gained from their professional training due to a lack of appropriate clinical placements. Progressive resistance training is a program typical of those that members of the community might undertake if they attended a community gym. The model developed and implemented in this study has the potential to become part of the on-going clinical experience of physiotherapy students and therefore could be an avenue for the long term sustainability of this type of community-based exercise program. It could also provide on-going opportunities for people with Down syndrome and those with other disabilities who require a high level of support to exercise. It is anticipated that, like with all novices, after a period of supervised exercise it may be possible for adolescents with Down syndrome to continue with the program with a lesser degree of supervision such as with a family member.

The main strength of the trial is that it was the first randomised controlled trial that assessed the effects of a progressive resistance training program among adolescents with Down syndrome. Of the previous four studies published, three included adults with Down syndrome (Davis and Sinning 1987, Rimmer et al 2004, Shields et al 2008), and the other was a non-controlled trial of 14 adolescents with Down syndrome (Weber and French 1988). An important aspect of the program was that it took place in an inclusive setting (a community gymnasium). This is noteworthy as adolescents with Down syndrome often have restricted opportunities to participate in exercise programs taking place in an integrated community setting (Menear 2007).

While the trial was powered to detect changes in lower limb muscle strength, a limitation was the relatively small sample size, which required the effects of the intervention to be large in order to detect any changes in task-related activities. However, the 95% CIs around the estimates of the effects on task-related outcomes include clinically worthwhile effects. Therefore, the trial provides important pilot data for the conduct of a randomised trial to define more precisely the effect of the training on task-related outcomes.

Other factors in the design of the intervention that could be considered are the duration and frequency of the program. Given its relatively short duration, it is possible that a larger effect might be obtained from continuing the program for longer. A study on people with intellectual disability reported greater gains in muscle strength from programs of longer duration and frequency (Suomi 1998). However, the 10-week program, had the advantage of fitting in with the typical school term and therefore could be timetabled around the weekly schedule of the families of the adolescents. Increasing the program frequency from twice to three times a week might change the outcome, as a previous study including adults with Down syndrome completed training three times per week and reported larger positive effects (Davis and Sinning 1987). However, it is not known what effect this change would have on program adherence in adolescents with Down syndrome.

There appeared to be a greater number of participants with moderate intellectual disability in the experimental group. It is possible that adolescents with moderate intellectual disability might find it more difficult to follow instructions and learn the exercises than adolescents with a mild intellectual disability, which could limit the benefit they obtain from the program. However, there was a very high adherence rate in participation in the intervention program by participants with moderate intellectual disability suggesting the intervention was well accepted and feasible.

A limitation of the study is that there was no follow-up as to whether the effects of the intervention were maintained and whether there were any longer term outcomes from engaging in regular progressive resistance training. Further studies are also necessary to help determine the long term sustainability of the program given the level of support that adolescents with Down syndrome need to begin to exercise. An additional outstanding issue that should also be addressed in future studies is whether progressive resistance training alone can change physical activity levels.

Progressive resistance training is one possible exercise and recreation option for adolescents with Down syndrome. Previous studies have investigated the effectiveness of other exercise options in this population such as aerobic training and circuit training (Khalili and Elkins 2009, Millar et al 1993, Weber and French 1988). The predominance of males who volunteered to participate in the current study might suggest that it is more socially desirable for males to take part in progressive resistance training. The prevalence of Down syndrome is approximately 10% higher among males than females (Shin et al 2009), so more males self-selected into this study than would be expected on the basis of population distribution alone.

In conclusion, progressive resistance training led by physiotherapy student mentors and performed in a community gymnasium is a feasible, socially desirable, and safe exercise option for adolescents with Down syndrome that can lead to improvements in lower-limb muscle performance. This trial provides important data that justify a future randomised trial to ascertain whether progressive resistance training carries over into an improved ability for adolescents with Down syndrome to complete daily tasks and physical activities. ■

eAddenda: Table 3 available at www.jop.physiotherapy.asn.au

Ethics: The trial received ethics approval from the La Trobe University Human Ethics Committee (08-024). Written informed consent to the research was obtained from the parents of all participants.

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