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Title:

The effects of progressive resistance training on daily physical activity in young people with cerebral palsy: a randomised controlled trial

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Abstract

Objective: To examine if individualised resistance training increases the daily physical activity of adolescents and young adults with bilateral spastic cerebral palsy (CP).

Design: A single-blinded randomised controlled trial

Setting: Community gymnasiums

Participants: Young people with bilateral spastic CP classified as Gross Motor Function Classification System levels II or III were randomly assigned to intervention (mean age: 18.2y, SD: 1.9y) or to usual care (mean age: 18.6y, SD: 2.9y).

Interventions: The intervention group completed an individualised lower limb progressive resistance training programme twice a week for 12 weeks.

Main outcome measures: The primary outcome was daily physical activity (energy expenditure, number of steps, and time sitting and lying). Secondary outcomes included muscle strength measured with a one-repetition maximum (1RM) leg press and reverse leg press. Outcomes were measured at baseline, 12 weeks, and 24 weeks by examiners blinded to group.

Results: From the 36 participants with complete data at 12 weeks there were no between-group differences for any measure of daily physical activity. There was a likely increase in leg press strength in favour of the intervention group (mean difference 11.8 kg; 95%CI: -1.4 to 25.0) but not for reverse leg press strength. No significant adverse events occurred during training.

Conclusions: A relatively short-term resistance training programme that may increase leg muscle strength was not effective in increasing daily physical activity. Other

strategies are needed to address the low daily physical activity levels of young people with bilateral spastic CP.

Clinical Trial Registration number: ACTRN12607000553471

Keywords: physical activity; motor activity; sedentary behaviour; sedentary lifestyle; resistance training, bilateral spastic cerebral palsy

Introduction

Daily physical activity levels of people with cerebral palsy (CP) are low [1,2]. Like the rest of the population, low levels of physical activity increases the risk of people with CP developing secondary health problems such as cardiovascular diseases, obesity or osteoporosis [3]. Low physical activity can also exacerbate some of the problems commonly associated with CP such as muscle weakness, stiffness and decreased mobility [4,5]. Therefore, it is important to know how to increase daily physical activity levels of people with CP.

Physical activity has been defined as “any bodily movement produced by contraction of skeletal muscles that results in energy expenditure” [6]. When investigating the relationship between physical activity and health it is necessary to measure daily physical activity [7]. Accelerometers have been widely accepted as useful objective measurement tools of daily physical activity [8]. Daily physical activity outcomes measured using accelerometer-based activity monitors include steps per day and time spent standing and from these energy expenditure can be estimated. Outcomes derived from activity monitors such as time sitting/lying are representative of a lack of daily physical activity or sedentary behaviours.

Evidence from a systematic review we conducted suggested that participating in exercise programmes such as aerobic training can increase the daily physical activity of people with CP [9,10]. Currently, however, there are no studies measuring the effects of resistance training on the daily physical activity of people with CP using objective outcome measures. Despite that, there is a rationale that exercise that focuses on strengthening weakened muscles to make movement easier might

potentially be a useful intervention for increasing the low physical activity levels of young people with CP. For example, lower limb flexor muscle strength has been found to be an important predictor of daily physical activity in young people with bilateral spastic CP [11].

Considering the above, the aim of this study was to determine whether a 12-week progressive resistance training programme for the lower limbs increased the daily physical activity levels of adolescents and young adults with CP who had difficulty walking.

Method

Study design

The research design was a single-blind randomised controlled trial of progressive resistance training compared with usual care. The results of the trial on outcomes of walking performance, functional mobility, gait characteristics and muscle performance outcomes have been reported [12]. The current paper reports the results of the intervention of progressive resistance training on daily physical activity.

Sampling and recruitment

Participants had to have bilateral spastic CP, be 14-22 years old and be classified as Gross Motor Function Classification System (GMFCS) level II or III. Volunteers were excluded if they had undergone single or multi-level orthopaedic surgery within the previous 2 years, if they had participated in progressive resistance training within 6 months prior to the start of the trial and if they had contractures of more than 20° at the hip and knee [13]. The trial was registered (ACTRN12607000553471), was approved by the relevant university and health services ethics committees and all

participants provided written informed consent. Participants were randomly allocated to the intervention or to the control group receiving usual care using a concealed method.

Intervention

Participants allocated to the intervention group completed a 12-week progressive resistance training programme with weight machines in community gyms under the supervision of a physiotherapist, either individually or in pairs. Participants completed 2 to 3 sets of 10 to 12 repetitions of each prescribed exercise twice weekly [14]. The load was the weight that participants could lift for 10 to 12 repetitions before they reached muscle fatigue [14]. When participants could complete 3 sets of 12 repetitions of an exercise without reaching muscle fatigue, the amount of weight lifted was increased at the next session. At the end of each training session, participants and their physiotherapist filled in a log book describing details of each exercise they had completed, as well as any adverse events such as pain due to training. Participants also completed a rating of perceived exertion at the end of each session to ensure they were training at sufficient intensity [15].

The exercises prescribed to each participant were based on instrumented 3-D kinematic and kinetic gait analysis, supplemented by a lower limb joint range of motion and a muscle strength clinical assessment. A median of 5 (range 4-6) exercises were prescribed for each participant and a median of 4 (range 2-5) muscle groups were targeted. A description of typical exercises prescribed is provided in Table 1. Intervention group participants were advised to stop training after the 12-week training period but to continue with their usual activities until the final testing session at 24 weeks.

Participants assigned to the control group continued their usual care during the 12-week intervention period. In that time they could continue with their usual recreation and physiotherapy provided these did not include progressive resistance training.

Outcome measures

Activity monitor (ActivPAL™) data were collected at baseline, immediately after the intervention (week 12), and again 12 weeks later (week 24). ActivPAL does not need individual calibration and uses an accelerometer to sense limb position and activity [16]. ActivPAL has demonstrated evidence of criterion validity in children, adolescents and young adults with cerebral palsy [17,18,19]. In our laboratory, the monitor predicted video observation measurements for physical activity outcomes ($R^2 \geq 0.96$) providing evidence of criterion validity in a group of 10 adolescents and young adults with bilateral spastic CP [19]. Retest reliability of the activity monitor was also tested in our laboratory on a group of 21 adolescents and young adults with bilateral spastic CP over 12 weeks and was found to be high for energy expenditure and number of steps (*Intraclass Correlation Coefficient (ICC) ≥ 0.85*), and moderate for daily time spent in sitting and lying (*ICC = 0.60 - 0.66*) [19].

Participants had an activity monitor attached on their thigh at a gait laboratory at all three assessments by research assistants blind to group allocation. Participants were instructed to wear the activity monitor for 7 consecutive days at each data collection period. They were advised to keep the monitor on all the time except during bathing, and swimming and were asked to continue with their usual activities during the recording period. They were also given a daily logbook to record when the monitor was taken off. The primary outcome measures (daily physical activity) comprised an estimate of energy expenditure, number of steps taken, and time spent in sitting and

lying (including sleeping). To estimate energy expenditure from activity monitor data, a metabolic equivalent value (MET) is assigned to sitting, lying and standing while the value for stepping increases with increased cadence [16].

Secondary outcome measures were one repetition maximum (1RM) of a leg press (combined hip extension, knee extension and ankle plantarflexion), and a reverse leg press (combined hip flexion, knee flexion and ankle dorsiflexion) as composite measures of lower limb strength. One repetition maximum can be measured with high levels of association ($r=0.89$) and responsiveness in people with CP [20].

Data analysis

For the current study, based on an observed effect size of $d=1.05$ of daily physical activity measured as energy expenditure after an aerobic exercise programme in young people with CP [9], a significance level of 0.05, and a power of 0.80 [21], it was determined that 15 participants would be required in each group. Effect size d is the difference between the experimental and control group post-intervention means divided by the pooled standard deviation.

Participant physical activity data were included for analysis if at least 2 full days (24 hours each day) of data were available. Periods as short as two days of monitoring have been used successfully to describe daily physical activity in people with CP [22,23]. Also, physical activity data collected for at least 2 full days with the ActivPAL monitor provided valid and reliable measurements in groups of young people with bilateral spastic CP [19].

The interaction effect of the two-way analysis of variance with one repeated factor (time) and one independent factor (group) was used to compare the groups for change

from baseline to 12 weeks and 24 weeks. Normality of distribution of the data was tested for each group. If data did not fulfil the assumption of normality, these data were transformed with natural log transformation and analysis was performed with both raw and log transformed data. Spearman's rho (r_s) was used to explore the associations between physical activity outcomes (baseline to 12 week differences) and lower limb strength (baseline to 12 week differences) for the intervention group (n=15).

Results

Figure 1 summarises participant flow through the study and reasons for missing data at 12 week and 24 week assessments. Forty-nine participants (intervention group: 24, control group: 25) were randomised. One participant withdrew from the intervention group after allocation but before the start of the training because surgery was scheduled unexpectedly. Daily physical activity data were collected on 15 participants in the intervention group and 21 participants in the control group at 12 weeks, and on 13 participants in the intervention group and 20 participants in the control group at 24 weeks. Main reasons for missing data were failure of the monitor to collect data (n=3), loss of the monitor when returning by mail (n=3), water damage of the monitor (n=2), taking off the monitor due to itching (n=2) and participant withdrawal from the trial due to surgery (n=2). At 12 weeks, physical activity data were available for at least 5 full days for 31 participants and for at least 3 full days for 35 participants.

At baseline the groups were relatively well-matched apart from weight where the control group was, on average, 9.9 kg (18%) heavier (Table 2). However, as weight was not found to be significantly associated with the daily physical activity of young

people with bilateral cerebral palsy in a previous study [11], weight was not included as a covariate in the main analysis (Table 2). At baseline, on average, participants in the intervention group expended 32.8 METs/day, took 5,808 steps/day and spent 19.4 hours/day in sitting/lying, while participants of the control group expended 32.2 METs/day, took 4,589 steps/day and spent 20.1 hours sitting/lying (Table 3).

Initially, an intention to treat analysis was planned for the main analysis of the outcomes [24]. However, because more than 10% of the data were missing in the intervention group at both post-intervention and follow-up assessments and cases with complete physical activity data were not different from cases with missing data regarding baseline characteristics ($p \geq 0.3$, Table 2), analysis was carried out using complete cases [25].

From baseline to 12 weeks, there was no difference between the intervention and control groups for any measure of daily physical activity or 1 RM leg press and reverse leg press strength (Table 3). However, there was an observed increase in 1 RM leg press strength in the intervention group compared to the control group (11.8 kg; 95%CI: -1.4 to 25.0) (Table 3). Data analysis for number of steps with log transformed data also did not find any difference between groups ($p= 0.20$). A per protocol sensitivity analysis was performed excluding two participants from the analysis who completed less than 80% of the 24 scheduled sessions during the 12-week intervention period. These results also did not show any between group differences for any of the daily physical activity measures ($p \geq 0.23$). No significant associations were observed between changes in physical activity and changes in lower limb muscle strength for the intervention group (r_s ranged in magnitude from 0.04 to 0.36).

At 24 week follow-up, there were no significant differences between the intervention and control groups for measures of daily physical activity or for 1 RM leg press and reverse leg press (Table 4).

There were no serious adverse events during the resistance training programme apart from minor musculoskeletal aches. No sessions were missed due to injury related to the training.

Discussion

The results of this trial suggest that participating in a 12-week progressive resistance training programme held in a community gymnasium might increase lower limb muscle strength, but does not increase the daily physical activity of adolescents and young adults with bilateral spastic CP and mild to moderate walking disabilities.

The results of the current study appear inconsistent with qualitative and subjective reports of improved activity after progressive resistance training. Improvements attaining statistical significance at 5% in self-reported functional mobility were reported in the young people with bilateral CP after the same 12-week resistance training programme (Functional Assessment Questionnaire mean difference: 0.8 units (95% *CI* 0.1-1.6); Functional Mobility Scale at 5 m mean difference: 0.6 units (95% *CI* 0.1-1.1) [12]. Also, increases in walking distance and the ability to perform physical activities such as jumping up or doing squats after progressive resistance training have been reported by people with CP in previous qualitative studies [26,27]. Although participants have reported improved functional mobility and this might be reasonably expected to increase the related construct of daily physical activity, when

measured objectively with an activity monitor these improvements were not observed. To explain this discrepancy, it is possible that participants believed their functional mobility and therefore perhaps their daily physical activity had improved because they expected that doing such a strenuous programme should improve this aspect of their performance. It is also possible that when participants of the qualitative studies reported increased physical activity they actually commented on improved functional ability/mobility and not on aspects of daily physical activity that were measured in the current study. For example, although their amount or intensity of daily physical activity had not changed, they may have been highlighting that they felt more confident to perform physical activities (e.g. “I could just walk easier, it was more flowing ... I think everything was easier”) [27].

Significant increases in the daily physical activity of young people with CP have been reported in two previous quantitative studies that did not implement progressive resistance training as an intervention [9,28]. One of these studies reported there was a significant increase in daily energy expenditure in children with CP after a 9-month aerobics exercise programme (effect size $d=1.1$; 95% CI 0.12-1.99) [9,10]. A possible reason for finding a significant increase in daily expenditure after an aerobics exercise programme may be that the programme was three times as long as the programme investigated in the current study. Maybe a long term programme is needed to embed changes in daily physical activity. Also, an aerobic intervention that involves more daily energy expenditure may be closer to the phenomenon being measured in daily physical activity so it is possible that such a programme could result in greater improvement in daily physical activity than resistance training.

Another quantitative study demonstrated significant increases in weekly step counts (effect size $d=0.62$; 95%CI 0.0-1.25) and weekly minutes spent in moderate to

vigorous physical activity (effect size $d=0.81$; 95%CI 0.17-1.45) after an on-line behavioural programme [28,10]. Daily physical activity is complex and related to psychological, social or environmental factors [29,30,31] as well as physical factors. It is, therefore, possible that a behavioural programme providing tailored activity feedback and specific activity goals [28] may be more effective in increasing daily physical activity in young people with CP than a resistance training programme. Addressing lower limb muscle strength alone without addressing psychological, social or environmental factors, may not have been sufficient to bring about increases in daily physical activity.

Another explanation for our results may be that our programme mainly focused on strengthening the lower limb extensors while strengthening of the lower limb flexors was prescribed for very few participants ($n=4$). Lower limb flexors strength has been found to be an important predictor of daily physical activity in young people with bilateral spastic CP and not lower limb extensors strength [11]. A further consideration is the observed phenomenon of resting after a bout of exercise [32]. It is possible that participants in the intervention group may have felt they had worked hard during the 12-week training period and that once this was completed they deserved or needed a rest. Hence, the reduction observed in daily physical activity immediately after finishing the 12-week training programme.

In the current study, no significant difference between the two groups was found for 1 RM leg press at post-intervention, although there was an observed increase in 1 RM leg press strength in the intervention group compared to the control group (11.8 kg; 95%CI: -1.4 to 25.1). The increase in 1RM leg press in the intervention group was 20% larger than in the control group. A significant difference in leg press strength was found in favour of the intervention group at post-intervention in the main trial

(14.8 kg; 95%CI: 4.3 to 25.3) [12], suggesting the current trial may have lacked power due to its smaller sample size.

A limitation of this study is that physical activity data were missing at 12 weeks and 24 weeks raising issues about the practicality of the activity monitor and methods used. However, the baseline characteristics of participants with missing data were not different to the baseline characteristics of participants with daily activity data. Therefore, the missing data were unlikely to have biased the conclusion that there was no difference in daily physical activity between the groups after 12 weeks. Also, estimates of energy expenditure expressed in METs were derived indirectly from the activity monitor, based on proprietary equations, so the accuracy of this measure is uncertain. However, from our laboratory data we know that METs can be measured with high retest reliability in young people with bilateral spastic CP ($ICC=0.85$), and the estimated values are consistent with other representations of physical activity derived from the activity monitor.

In conclusion, although increased muscle strength in targeted muscles was observed in the intervention group, this clinical trial did not provide evidence that a progressive resistance training programme can increase daily physical activity in adolescents and young adults with bilateral spastic CP.

Ethical approval

This study was reviewed and approved by the La Trobe University and Royal Children's Hospital Ethics committees (ref: 08-012 and 28006C)

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Conflict of interest

None

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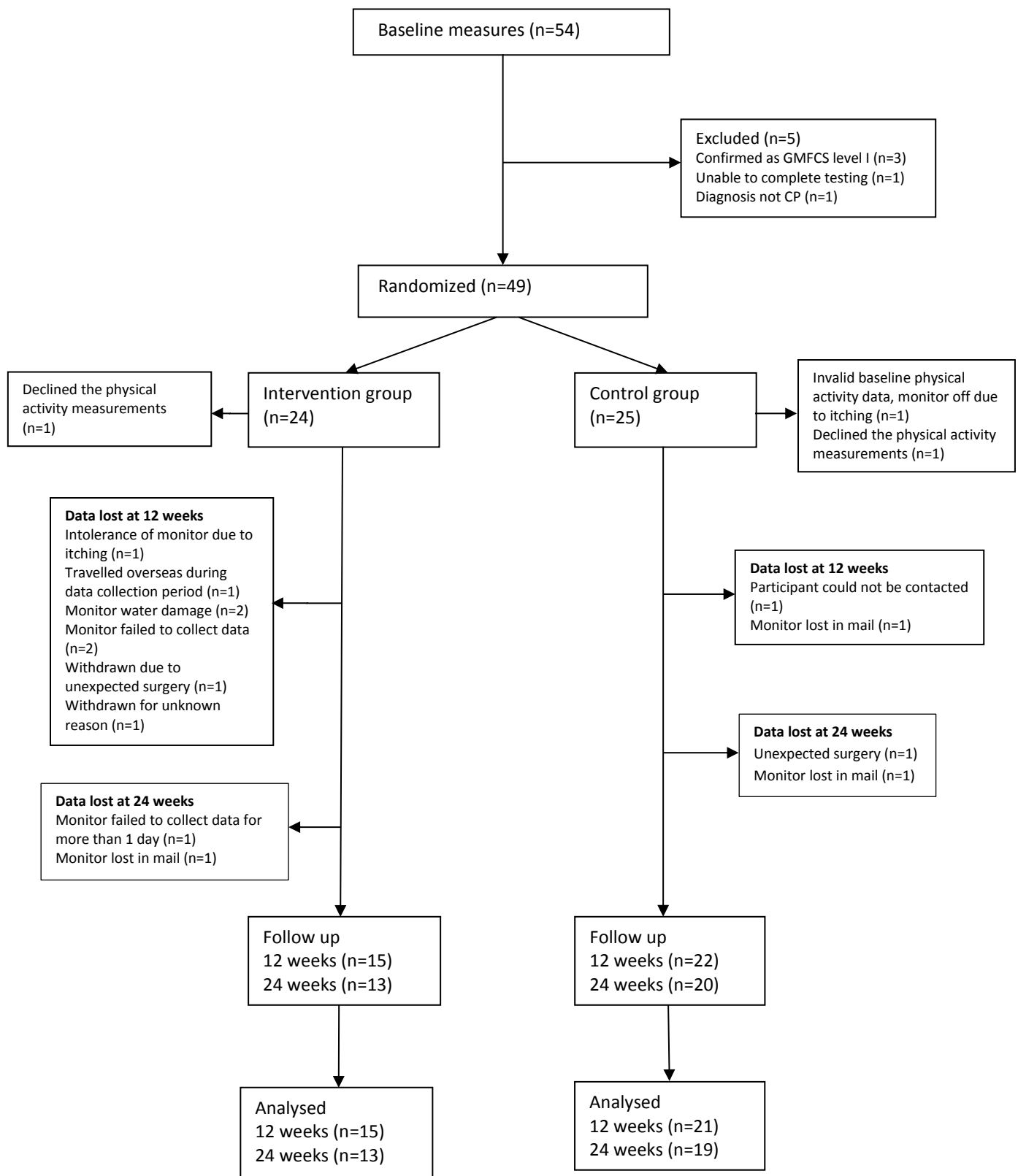


Figure 1: Participant flow through the stages of the randomized controlled trial.

1

2

Table 1 Description of an example of progressive resistance training programme

Exercise name	Exercise description
1. Leg press	Sitting, hips and knees at an angle of at least 90 degrees, slowly push both feet against resistance plate to fully extend the knees
2. Seated knee extension	Sitting, knees flexed 90 degrees, resistance bar positioned over distal anterior shin, extend both knees against resistance to full extension
3. Calf raise in standing	Standing with feet over edge of support with the ankle in plantigrade. Shoulders placed under resistance bar. Maintaining knees close to extension, slowly rise onto the balls of the feet.
4. Hip abduction in standing	Standing, resistance bar at outer side of the distal thigh, abduct thigh about 20 to 30 degrees against resistance, maintaining neutral posture of the stance leg.
5. Hip extension in standing	Standing, with strap attached to ankle from pulley. Slowly flex non-stance hip about 20 to 30 degrees, with the stance leg using extensor muscles to maintain posture.
6. Reverse leg press	Sitting with strap attached to front of ankle from pulley, hips and knees at full extension. Slowly pull foot up against resistance to a position of hip flexion, knee flexion and ankle dorsiflexion.

Table 2 Participants characteristics at baseline

	Whole sample N=48	Complete cases (n=36)	Experimental group (n=15)	Control group (n=21)	Comparison between experimental (n=15) and control group (n=21)	Cases with missing data (n=12)	Comparison between complete cases (n=36) and cases with missing data (n=12)
Mean age, years (SD)	18.4 (2.4)	18.7 (2.3)	18.2 (1.7)	18.9 (2.7)	$p= 0.3$	17.5 (2.7)	$p= 0.6$
Gender, n (%)							
Males	26 (54)	18 (50)	8 (53)	10 (47)	$p= 0.7$	7 (58)	$p= 0.6$
Mean height, cm (SD)	163.6 (10.5)	162.9 (10.2)	163.0 (12.2)	162.9 (8.9)	$p= 0.9$	165.6 (11.4)	$p= 0.8$

Mean weight, kg (SD)	58.9 (14.5)	60.2 (14.6)	54.4 (12.9)	64.3 (14.6)	$p= .04$	55.5 (14.1)	$p= 0.9$
GMFCS level, n (%)							
II	29 (60)	23 (64)	10 (67)	13(62)	$p= 0.8$	7 (58)	$p= 0.7$
III	19 (40)	13 (36)	5 (33)	8 (38)		5 (42)	
Orthotics, n (%) Yes	19 (40)	13 (36)	6 (40)	7 (33)	$p= 0.7$	6 (50)	$p= 0.4$
Gait aid use, n (%)							
No gait aid	28 (58)	22 (61)	9 (60)	13 (62)	$p= 0.5$	6 (50)	$p= 0.6$
Sticks	10 (21)	7 (19.5)	3 (20)	4 (19)		3 (25)	
Crutches	4 (8)	2 (5.5)	0 (0)	2 (9.5)		2 (17)	
Walker	6 (13)	5 (14)	3 (20)	2 (9.5)		1 (8)	

Previous single-event
multi-level surgery,

n (%) Yes	22 (46)	15 (42)	5 (33)	10 (47)	<i>p</i> = 0.4	7 (58)	<i>p</i> = 0.3
Mean time surgery (SD)	7.3 (3.0)	7.4 3.0	5.4 (2.6)	8.4 (2.9)	<i>p</i> = 0.8	7.0 (3.2)	<i>p</i> = 0.7

Hip morphology,
n of hips (%)

Grade I, normal hip	4 (4.5)	3 (4.5)	0 (0)	3 (8)	<i>p</i> = 0.2	1 (4)	<i>p</i> = 0.3
Grade II, near normal	50 (55.5)	33 (50)	12 (43)	21 (55)		17 (71)	
Grade III, dysplastic hip	35 (39)	29 (44)	15 (53.5)	14 (37)		6 (25)	
Grade IV, subluxated hip	1 (1)	1 (1.5)	1 (3.5)	0 (0)		0 (0)	

Table 3 Results after the intervention (12 weeks)

Outcomes	Baseline		12 weeks		Difference within groups		Difference between groups
	mean		mean		(12 weeks minus baseline)		(Intervention minus control)
	<i>(SD)</i>		<i>(SD)</i>				
	Intervention	Control	Intervention	Control	Intervention	Control	(95% confidence interval)
	(n=15)	(n=21)	(n=15)	(n=21)			
1 RM leg press strength (kg)	92.0 (36.7)	83.0 (32.5)	106.1 (39.8)	84.6 (30.5)	14.1 (23.3)	2.3 (13.9)	11.8 (-1.4 to 25.1)
1 RM reverse leg press strength (kg)	16.4 (9.2)	16.0 (10.4)	14.8 (10.1)	15.8 (11.1)	-1.6 (15.9)	-0.2 (18.5)	-1.4 (-14.0 to 11.0)

Energy	32.8	32.2	32.6	32.0	-0.18	-0.20	0.02
Expenditure (METs/day)	(1.5)	(1.2)	(1.5)	(1.0)	(1.2)	(0.61)	(-0.6 to 0.6)
Number of steps/day	5,808 (3,627)	4,589 (2,851)	5,368 (3,735)	4,178 (2,401)	-440 (2,625)	-411 (1,301)	-28 (-1373 to 1317)
Time spent in sitting and lying (h/day)	19.4 (1.3)	20.1 (1.6)	19.7 (1.5)	20.5 (1.6)	0.31 (1.4)	0.37 (1.3)	-0.06 (-0.9 to 0.8)

kg= kilograms, METs metabolic equivalents, n= group size; raw data are presented for steps, RM=repetition maximum; leg press and reverse leg press data were available for 14 participants (intervention group) and 19 participants (control group)

Table 4 Results at follow-up (24 weeks)

Outcomes	Baseline		24 weeks		Difference within groups		Difference between groups
	mean		mean		(24 weeks minus baseline)		(Intervention minus control)
	<i>(SD)</i>		<i>(SD)</i>				
	Intervention	Control	Intervention	Control	Intervention	Control	(95% confidence interval)
	(n=13)	(n=19)	(n=13)	(n=19)			
1 RM leg press strength (kg)	84.3 (24.6)	85.6 (31.9)	101.9 (41.5)	89.4 (28.3)	17.6 (31.8)	3.8 (18.6)	13.8 (-4.9 to 32.5)
1 RM reverse leg press	16.2 (9.5)	16.05 (10.7)	12.2 (9.3)	11.4 (11.4)	-4.0 (4.8)	-3.4 (7.6)	-0.6 (-5.7 to 4.5)

strength (kg)

Energy	32.9	32.2	32.4	32.2	-0.51	-0.02	-0.49
Expenditure (METs/day)	(1.6)	(1.3)	(1.2)	(1.3)	(0.70)	(0.67)	(-0.9 to 0.006)
Number of steps/day	6,071 (3,906)	4,551 (2,979)	5,119 (2,772)	4,693 (3,205)	-952 (1,692)	141 (1,644)	-1093 (-2316 to 130)
Time spent in sitting and lying (h/day)	19.3 (1.4)	20.2 (1.6)	20.0 (1.1)	20.6 (1.4)	0.69 (0.96)	0.44 (0.79)	0.31 (-0.38 to 0.9)

4 kg= kilograms, METs metabolic equivalents, n= group size; *raw data are presented for steps*, RM=repetition maximum; leg press and reverse leg press data were available
5 for 12 participants (intervention group) and 18 participants (control group)

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