Effects of Adaptive Bungee Trampolining for Children With Cerebral Palsy: A Single-Subject Study

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Purpose: To assess effects of adaptive bungee trampoline training for children with cerebral palsy.
Methods: This was a single-subject intervention study, A-B-A, with 4 children aged 6 to 11 years. Measurements included muscle strength, balance, functional muscle strength, functional mobility, selected Gross Motor Function Measure items, heart rate, enjoyment, and for adverse effects—range of motion and spasticity. Goals were measured using the Canadian Occupational Performance Measure.
Results: Lower limb muscle strength improved in 3 children, and balance and functional strength in 2 children. The child who was not walking increased sitting and supported standing times. All participants had clinically significant increases on the Canadian Occupational Performance Measure. Adherence and enjoyment were high, with no adverse effects.
Conclusion: Adaptive bungee trampoline training can improve strength, balance, and functional mobility in children with cerebral palsy. (Pediatr Phys Ther 2019;31:165–174)
Key words: adaptive equipment, balance, fun, function, goal-orientated, muscle strength, pediatric rehabilitation, physical activity, physical therapy, trampoline

INTRODUCTION

Cerebral palsy (CP) is caused by a nonprogressive brain lesion resulting in permanent physical impairments, which can vary, depending on lesion location.[1] It is recommended that all children, including children with disability, participate in moderate to vigorous physical activity (PA) for 60 minutes and spend less than 2 hours being sedentary daily for numerous health-related benefits.[2] Children with CP do not meet these guidelines, and participate in less PA than children developing typically.[3] This lack of participation in PA can be secondary to reduced gross motor functioning and/or the functional challenges that may arise with different types of PA.[4] Limited opportunity to practice specific sports or PA, or limited accessibility to facilities, may also be barriers that restrict PA.[4]

It is important to find physical activities that are accessible by children with CP at *all* levels of the Gross Motor Function Classification System (GMFCS). Compared with children with milder impairments, it is more challenging to find a variety of activities for children classified as GMFCS levels III to V. It is particularly important as they tend to be more sedentary and participate less in PA than children classified as GMFCS levels I and II,[3,5] likely owing to limited access to available activities.[4] A framework for children with neurodisabilities identified 6 key areas of child development: function, family, fitness, fun, friends, and future. These concepts should be adopted in clinical practice and research.[6] This framework proposes that there is a need for more recreational opportunities for all children with disabilities, even if not therapeutic, suggesting that to increase or enhance participation there needs to be an emphasis on fun.

A safe trampoline along with suitable supervision can be fun for children with CP and also affords benefits for function and physical fitness. The benefits of trampolining have been studied in other clinical populations, such as in children with developmental coordination disorder and people after stroke, with improvements in balance, strength, and muscle coordination.[7-10] The rationale for trampolining as a rehabilitative environment in these studies was that the unstable

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trampoline surface stimulates righting reactions, with activation of ankle muscles and activation of core and postural muscles to remain upright.[8] However, there is limited evidence in children with physical disabilities concerning the effects of a trampoline program as an intervention or as a form of PA. There are no published studies of bungee trampolining that provide body-weight support in children with physical disabilities, particularly children with more severe physical impairments (ie, GMFCS V). Given the popularity of trampolining as a fun activity for children, it may be considered as an approach to pediatric rehabilitation.

The primary aim of this study was to assess the effects of a 12-week adaptive bungee trampoline program on goal-derived measures in children with CP. We hypothesized that 12 weeks of bungee trampoline training could improve lower limb muscle strength, improve functional ability, and provide a form of moderate-intensity PA. The secondary aim of the study was to measure levels of participation in the bungee trampoline program and determine whether this type of training is an enjoyable intervention for children with CP.

METHODS

Study Design

This pilot study employed an A-B-A single-subject research design (SSRD)[11] with a 5-week pretrampoline phase (A), 12-week intervention phase (B), and a follow-up assessment (A) 4 weeks after intervention for participants 1 to 3, and 10 weeks after intervention for participant 4. Participant 4's postintervention assessment was delayed owing to sleep difficulties affecting his mood and ability to complete measurements.

The use of an SSRD allowed for individualized interventions on the trampoline and individualized assessments dependent on the family's goals, and the child's GMFCS level and cognitive ability. This individualized approach enabled monitoring of each child's response to the intervention. This is of value due to the heterogeneity among children with CP. The study protocols were approved by the University's Human Research Ethics Committee (HRE2016-0126).

Participants

Participants were recruited through Ability Centre, a disability therapy service provider in Western Australia. A single-group e-mail invitation was sent to 381 families, with 29 expressions of interest returned. Potential participants were screened by assessors to select 4 participants across the range of GMFCS levels without medical contraindications preventing the children from participating in the intervention (see Table S1, Supplemental Digital Content 1, available at: http://links.lww.com/PPT/A246). Written and verbal consent was obtained from a parent, and where possible, the child.

Equipment

An adaptive bungee trampoline was designed by engineers at Dreamfit, an equipment design and manufacturing service for children with disabilities at Ability Centre. The adapted bungee trampoline included a harness connected to a support frame with 5 bungee cords, enabling children with physical disabilities to access the trampoline. The cords could be adjusted to alter the level of support of the body weight for each child, and the effort required for jumping tasks (Figure 1).

Intervention

The bungee trampolining program lasted 12 weeks including 2, 30-minute trampoline sessions per week with individualized activities depending on the child's capabilities and goals (see Table S2, Supplemental Digital Content 2, available at: http://links.lww.com/PPT/A247). All sessions included stretching the gastrocnemius and hamstrings. Other activities included bouncing or being bounced, hopping, heel jumps, jumping with eyes closed, practicing a sequence of jumps within the child's capability, and games such as dodgeball. Each week, the first session was conducted by a pediatric physical therapist and the other session by a physical therapist student. There was typically 1 session on a weekday and the second session on a Saturday separate from therapy or other intervention. Each session's activities and intensity, measured by a heart rate monitor every 5 minutes, was recorded in a participant diary.

The participants were instructed to continue their usual daily activities during this block of trampoline training including school, other sporting commitments, and normal therapy routines. These were recorded in activity diaries by participants' parents. Participant 4 received botulinum neurotoxin

Fig. 1. The adapted bungee trampoline in use.

type A (BoNT-A) treatment on week 10 of the intervention phase to bilateral tibialis posterior (25 μ each). No other participants received BoNT-A treatment during the study period. There were no changes in physical activities during the study period.

Assessments

Once a week, assessments for participants 1 to 3 were performed by 1 assessor on the second weekly session. Weekly assessments for participant 4 were collected by another assessor before their first session. During the intervention weeks, assessments were completed before the trampoline session. Rest was provided between assessments to minimize fatigue.

The Canadian Occupational Performance Measure (COPM)[12] was a probe assessment, performed at the start and end of the phase (A), at the end of the intervention phase (B), and at the follow-up assessment (A). Participant 4, however, only completed the COPM at the start of the baseline and end of the intervention phase. The COPM was used to measure treatment-related, individualized, parent-nominated goals. The COPM has been validated to compare outcomes of an intervention program in individuals with CP.[12] A maximum of 3 goals were set for each child by the parent, based on the child's daily life. Each parent was asked to rate the child's performance of the goals that they had suggested at the beginning of the study, and their satisfaction with this performance, on a 10-point ordinal scale. Parent ratings for the 3 goals were averaged in accordance with COPM scoring instructions. The parents were masked to their previous scoring.

The measurements in the first phase of the study, and at the follow-up assessment, were taken at each child's home at the family's convenience. During the 12-week intervention phase of the study, assessments were completed at the site of the trampoline training. Measurements were collected for both lower limbs, even if the child was unilaterally affected.

Range of Motion. Range of motion (ROM) was assessed to ensure no negative consequences to muscle length and joint ROM occurred as a result of the trampoline training. Measurements of passive ankle dorsiflexion and plantar flexion in subtalar neutral (in knee flexion and extension), knee flexion, knee extension, popliteal angle, and hip flexion were taken in the supine position. Passive hip extension was measured in the prone position.

Spasticity. Spasticity of the gastrocnemius and hamstrings was assessed using the Modified Tardieu Assessment and the Australian Spasticity Assessment Scale using previously published protocols.[13] The muscle groups were tested in a supine position. Two clinical measures of spasticity were included to improve both the chance of detecting any increases in spasticity in the major muscle groups during the trampolining, and our confidence that no adverse effect on spasticity occurred from the intervention. Reliability of the Australian Spasticity Assessment Scale exceeds other published clinical assessments of spasticity (intraclass correlation coefficient [ICC] = 0.88).[13]

Strength. Three strength measures were used. Individual muscle strength of lower limb muscle groups was measured using a hand-held dynamometer (Power Track II Commander, JTECH Medical, Salt Lake City, Utah). For each muscle group, the maximum result of 3 muscle contractions was used. Muscle groups were ankle plantar flexors, ankle dorsiflexors, quadriceps, hamstrings, hip extensors, and hip abductors. To reduce measurement error, the same stabilization strategy was used each week following the protocol from Crompton et al,[14] which has acceptable reliability (ICC > 0.70) to determine changes in muscle strength in children with CP.

Single-limb heel raises provided a measure of functional strength of the ankle plantar flexors.[15] The maximum number of heel raises performed on each leg was recorded. Measurement was continued until the participant (*a*) was unable to achieve rise onto the metatarsal heads; (*b*) used excessive upper limb support on a wall (more than fingertip support); or (*c*) placed the opposite foot on the floor.

Functional muscle strength of the larger lower limb muscle groups that are important in daily activity was measured using the 30-second lateral step-up test,[16] the 30-second sit-to-stand test,[16] and the 30-second half kneel-to-stand test.[16] The total functional muscle strength was calculated by adding the maximum number of repetitions achieved in each activity (eg, 5 step-ups on the left and right leg, plus 8 sit-to-stands, plus 2 half kneel-to-stands on the left and right legs gives a total functional muscle strength score of 22). Construct validity for this test has been demonstrated with moderate to high correlation between functional muscle strength, and gross motor capacity as measured with dimensions D and E of the Gross Motor Function Measure (GMFM).[17] There is acceptable reliability for this measure of functional strength (ICC $\geq$ 0.91).[16] Both assessors were trained and familiarized with the assessment by the same senior clinician to maximize standardization of the testing procedures. We did not measure reliability between the 2 assessors in this study and we relied on previously published values.

Balance. Standing balance was assessed using single-limb stance (SLS) time.[18] The maximum time of the 3 trials was recorded. Participants were asked to place their hands by their side or on their hips with the leg not tested kept in a position of 90° knee flexion. The test was ceased if participants (*a*) placed their foot on the floor, (*b*) excessive postural sway requiring upper limb support to regain balance, or (*c*) had to shuffle to maintain balance on the leg being tested. The modified Timed Up and Go (TUG) was used to determine dynamic balance, with the fastest time of 3 trials analyzed.[19] This was modified as the participant was asked to stand when the assessor said, "go," walk, and touch a target on the wall, and return to sit on a chair.

Functional Mobility. A 2-minute walk test (2MWT) was used in preference to the 6-minute walk test to minimize fatigue before the trampoline session. The 2MWT is a feasible submaximal exercise test for children with, or without, neuromuscular disorders aged 6 to 12 years, with excellent reliability.[20] A 10-m walkway was marked using 2 cones at either end.

Gross Motor Function Measure. Two modified goal-related items (34 and 53) from the GMFM[21] were used for participant 4. Length of time (seconds) sitting propping with arms and standing with both hands held was recorded. The best of 3 trials was used for each assessment.

Enjoyment. Enjoyment was measured after each trampoline session using a 5-point ordinal scale involving a series of faces, 5 representing "lots of fun" and 1 representing "not very fun." The children were asked to pick the face which best represented their enjoyment of that session. Participant 4's parents rated his enjoyment due to his cognitive impairment.

Heart Rate. Participants' heart rates (HRs) were monitored every session using Polar Heart Rate monitor (FT watch/T31 transmitter Polar Electro Oy, Kempele, Finland) and recorded at 5-minute intervals. Verschuren et al[22] determined that the maximum HR in children with CP is 200 beats/min, with the understanding that HR maximum has a large degree of interindividual variability. Participants' HRs were recorded every 5 minutes in the training diary, and used to determine the percentage of the total session time the participant was working at either light (50%-63% HR maximum), moderate (64%-76% HR maximum), or vigorous (77%-93% HR maximum) intensity.[23] The percentage of time each participant spent working at moderate or vigorous intensity was averaged across all sessions.

DATA ANALYSIS

Goal-related outcomes were selected for each child and graphed. Weekly data were recorded for each participant, with means and standard deviations calculated for each study phase. The weekly data included ROM, spasticity, strength using a dynamometer, single-limb heel raises, functional muscle strength, SLS, modified TUG, 2MWT, and 2 modified goal-related items from the GMFM for participant 4. The complete set of outcome measures was only assessed at probe time points (COPM). Changes in level between baseline and intervention phases were examined using (*a*) visual analysis of the graphs by a single observer using a yes/no rating scale, (*b*) the 2-standard deviation band (2SD) method, (*c*) percentage of nonoverlapping data (PND), and (d) standard mean difference (SMD).[11,24]

Session enjoyment was recorded in each participant's training diary, and the total percentage of sessions scored as 4 ("fun") or 5 ("lots of fun") across all sessions was calculated for each participant.

RESULTS

Participant Characteristics, Attendance, and Missing Data

Table 1 has the characteristics of the 4 children in the study and their participation rates. Participant 2 attended all trampoline sessions. Participants 1 and 3 attended 95.6%, and participant 4 attended 82.6% of trampoline sessions. Weekly assessments were taken on all children with 3 exceptions: (*a*) no measure was taken for all participants in the first week of phase B due to venue accessibility difficulties; (*b*) participant 1 missed session 15 due to illness; and (*c*) participant 4 did not attend 2 assessments in the baseline period and 2 sessions in the intervention period, due to sleep difficulties. Out of the 18 assessment time points, GMFM data were not recorded for 10 and 7 time points for items 34 and 53 respectively, due to family time constraints.

Effects of the Intervention

The goals of each participant are in Table 2. Goal-related outcomes for each participant were graphed (Figures 2-5). Results for all participants are in Table 3. Outcome measures differed for each child, depending on their goals. For example, participants 1, 2, and 3 had goals related to jumping, skipping, running, and balance. Changes in the strength of lower limb muscles required for these activities were investigated, as well as balance. Goals for participant 4 focused on fun and being able to assist with standing transfers. Changes in the GMFM items[21] related to these were investigated. Baseline stability was established for most, but not all outcomes measures, providing a clear comparison for the intervention phase in most instances. There was evidence of some significant improvements between baseline and intervention phases in lower limb muscle strength in the 3 children who were walking, and some significant improvements in balance (as measured by SLS and TUG) for participants 1 and 2. Functional strength improved for participants 2 and 3. Most of these changes were supported by at least 3 of the 4 methods of analysis: visual analysis, 2SD method, PND, and SMD (Table 3). There was no improvement in 2MWT for participant 2. Participant 4 increased the length of sitting and supported standing times. Most of these improvements appeared to be maintained at follow-up, although no statistical tests were performed on follow-up data because there was only 1 follow-up assessment.

The results of the COPM, indicating the parents' rating of their child's performance of goals and satisfaction with their achievement, are graphed in Figure 6. All participants had a change of 2 or more points in both performance and satisfaction between probes taken at the baseline and end of the intervention, indicating a clinically significant improvement in individualized goals.[26]

There was no loss of ROM or increases in spasticity of hamstrings, gastrocnemius, or soleus as a result of the intervention.

Heart Rate

The overall percentage of time that each participant spent in moderate- or vigorous-intensity activity is in Table 1. Moderate-intensity activity was achieved for the entire session by participant 1 on 3 occasions, by participant 2 on 6 occasions, and by participant 3 on 2 occasions. Participant 4 achieved moderate-intensity activity in 2 sessions, but only for 5 minutes at a time.

Enjoyment

The percentage of trampoline sessions rated as "lots of fun" was 82% by participant 1, 87% by participant 2, 77% by participant 3, and 58% by participant 4's parents (Table 1). The percentage of sessions for which the participants gave enjoyment ratings of either 4 and 5 were 100%, 96%, 82%, and 95%, respectively.

DISCUSSION

This is the first study investigating the effects of an adaptive bungee trampoline in children with CP. Results supported

TABLE 1

Participant Characteristics, Attendance, Enjoyment, and Intensity of Activity

	Participant 1	Participant 2	Participant 3	Participant 4
Participant characteristics				
Age at start of baseline, y	6.1	7.8	8.0	11.1
Sex	Female	Female	Male	Male
GMFCS	I	I	II	V
Neuromotor abnormality			Spastic	Spastic
Topographical involvement	Asymmetrical diplegia	Right hemiplegia	Diplegia	Quadriplegia
Bungee trampoline sessions				
Attendance, % of all sessions	95.6	100.0	95.6	82.6
Average session time, min	22.6	26.1	22.1	22.1
Average enjoyment[a], % of 5's	82.0	87.0	77.0	58.0
Moderate-intensity activity[b], % of time	60.3	73.9	37.6	0.9
Vigorous-intensity activity[c], % of time	5.3	15.2	1.0	0.0

Abbreviation: GMFCS, Gross Motor Function Classification System.

[a]Enjoyment was calculated based upon the percentage of 5's, representing "lots of fun," self-reported by each participant across all sessions. Participant 4's enjoyment levels were parent-reported.

[b]Moderate-intensity activity equates to 64% to 76% of maximum heart rate. The percentage in the table portrays the percentage of time the participant spent working at moderate-intensity activity across all sessions attended.

[c]Vigorous-intensity activity equates to 77% to 93% of maximum heart rate. The percentage in the table portrays the percentage of time the participant spent working at vigorous-intensity activity across all sessions attended.

the hypothesis that bungee trampoline training improves goal-related outcomes for ambulant children in regard to lower limb muscle strength and functional ability, and provides a form of light- to moderate-intensity activity. The child who was not walking improved in goal-related items on the GMFM.

Previous trampoline studies[7-10] used a generalized exercise program whereby each series of activities was the same for all participants, and on primarily a minitrampoline. In contrast, this study used a large trampoline, with a harness and bungee cords, which afforded larger jumps and individualized programs. Goal-orientated, individualized programs have provided better functional results in children with CP than more generalized therapy approaches.[27] The underpinning element of the bungee trampoline training was the participant's goals and,

TABLE 2

Participant Goals

Goals	Outcome Measures Assessed
Participant 1	
Would like to be able to skip	COPM
Would like to be able to run longer distances and keep up with her friends	Lower limb muscle strength
Would like to be able to stop and start running more easily	Heel raises
Would like to be able to hop	Functional muscle strength
	Single-limb stance time
	Modified Timed Up and Go
Participant 2	
Would like to have more strength in her right foot and ankle; be able to lift up her right foot more	COPM
	Lower limb muscle strength
Would like to trip over less	Heel raises
Would like to be able to skip and run better	Functional muscle strength
	Single-limb stance time
	Modified Timed Up and Go
	2-min walk test
Participant 3	
Would like to be able to push off his toes and have stronger calf muscles	COPM
Would like to be able to jump	Lower limb muscle strength using hand-held dynamometry
Would like to have more core strength and walking stability	
	Functional muscle strength
	Modified Timed Up and Go
Participant 4	
Would like to have fun on the trampoline	Modified GMFM item 34
Would like to jump	Modified GMFM item 53
Would like to be able to stand up better to facilitate standing transfers	

Abbreviations: COPM, Canadian Occupational Performance Measure; GMFM, Gross Motor Function Measure.

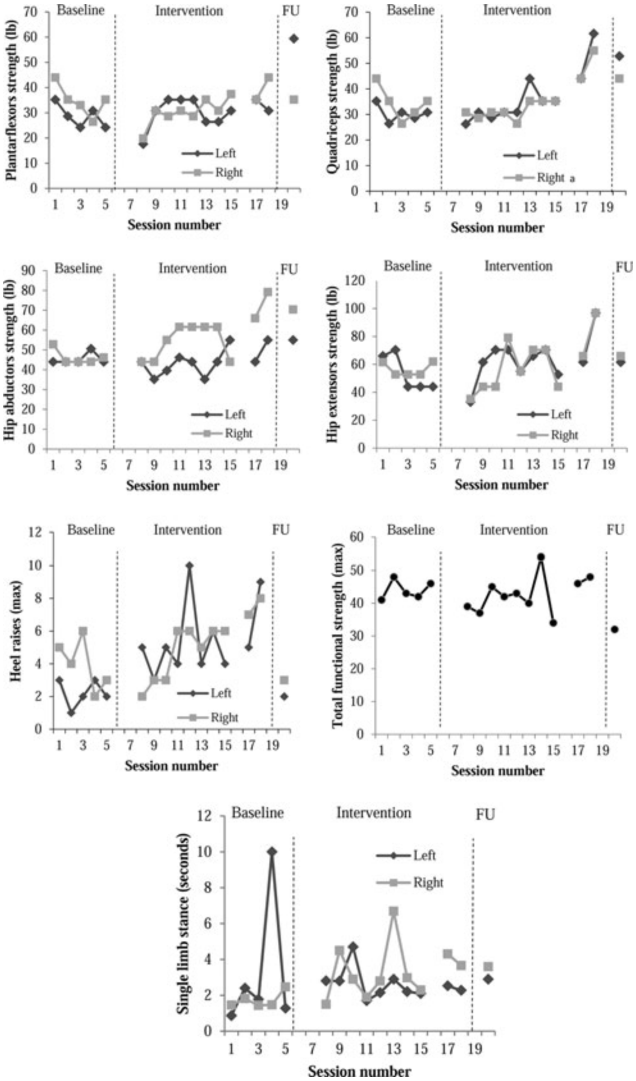

Fig. 2. Weekly goal-related results for participant 1.

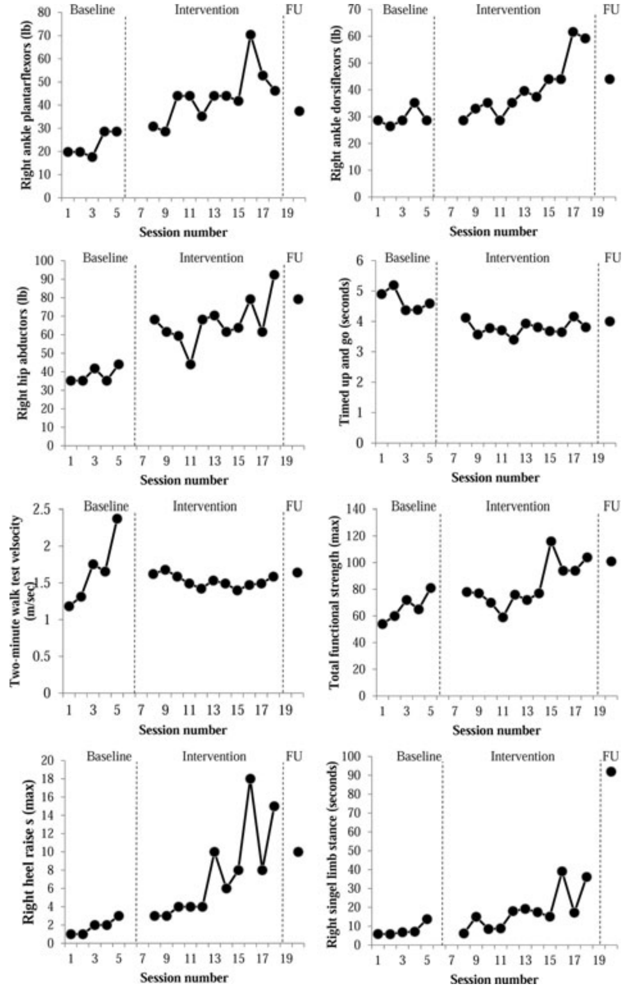

Fig. 3. Weekly goal-related results for participant 2.

because of the study design, both the assessments and activities on the trampoline could be individualized.[11] Goal-related improvements and high parent satisfaction for all participants were reflected in the clinically significant changes seen in the COPM.

The significant improvement in strength for participants 1 to 3 was consistent with the parents' COPM ratings. Activities performed on the trampoline were functionally based, with the bungee support allowing tasks that were too difficult on land to be performed on the trampoline. Improvements in hip abductor muscle strength were observed in participants 1 to 3, possibly because (*a*) the training resulted in a more optimal activation of the hip abductor muscle group due to improved motor control on the trampoline, and/or (*b*) during training these participants performed single-limb activities (eg, hopping) that recruited the hip abductors to stabilize the pelvis in a frontal plane—activities that they would not have been able to perform on land or without bungee support. Participant 2 (but not participants 1 and 3) had a clinically important change (of 9 points) on the functional muscle test.

Participants 1 and 2, who were both classified as GMFCS level I, had improvements in balance. These improvements in the participants with more function may be related to the more challenging tasks they performed on the trampoline, such as jumping on heels, jumping with less body weight support, or completing activities with eyes closed. Participants 3 and 4 did not engage in those activities. The more challenging tasks (such as performing jumping routines while throwing a ball[7] or jumping with one foot in front of the other[8,10]) completed by participants 1 and 2 are similar to activities completed in previous trampoline studies that found similar improvements in balance, as measured by the Berg Balance Scale and the TUG.[8,10] Balance improvements for participants 1 and 2 may have been due to the larger variety of tasks they performed on the unstable trampoline surface, which caused complex sensory-motor stimulation and therefore adaptations to maintain balance.[7,10]

Activities performed on the trampoline were tailored to each participant's capability and, therefore, all activities were successfully completed. Successful completion potentially contributed to an increase in participant confidence. Improved confidence addresses a common barrier to participation for children with CP. If children cannot complete a task, they perceive it as too difficult and not fun.[4] The bungee trampoline had high self-rated

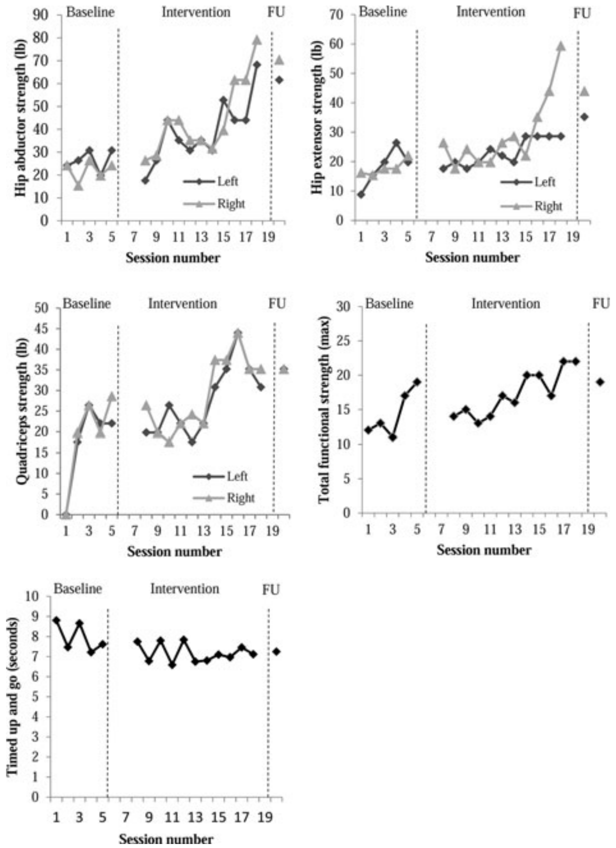

Fig. 4. Weekly goal-related results for participant 3.

or parent-rated enjoyment. Few ratings were below 4, and when they were, it was because the session was considered hard work or tiring. The participants were allowed choice in activities they performed on the trampoline. Lauruschkus et al[28] found that children with CP prefer to select what they perform when participating in PA and have higher enjoyment levels as a result. The engagement in the program was reflected through a high adherence rate.

Children with CP, particularly those who have less function, have difficulty achieving and maintaining moderate to vigorous levels of activity, and research suggests that any intervention that reduces sedentary time and provides light-intensity activity is beneficial.[29] In addition, cardiorespiratory fitness recommendations in individuals with CP recommend continuous exercises that involve major muscle groups for a minimum duration of 20 minutes.[2] These guidelines for continuous, light-intensity activity were met on the bungee trampoline for all participants, and therefore it may be a suitable alternative to increase PA levels for children with CP.

The trampoline was accessible and safe for all participants, including participant 4, who was classified as GMFCS V. As a barrier to participation in PA for children with CP is accessibility,[4] a strength of this study is the inclusion of ambulant and nonambulant children. In addition, there were therapeutic benefits to participant 4's participation including functional improvements indicated by increases in the time that he could sit unsupported and stand with hands held, and reflected in his parents' COPM ratings, which related to his ability to perform standing transfers. This is particularly important to prevent functional decline.

Limitations

This study met 10 of the 14 criteria on the Critical Appraisal Tool for SSRD, making it a moderate-quality study design.[30] The reasons for the unmet criteria were (*a*) the assessor's reliability was not evaluated as previously established protocols were followed using reliable outcome measurements; (*b*) blinding of assessors was not feasible owing to insufficient funding; (*c*) baseline stability was established for most participants on most variables, but not all; (*d*) participant 4 had insufficient time points during the baseline phase to establish stability, completing only 3 data points. The follow-up period was limited for practical considerations, but a follow-up of 3 to 6 months would be desirable. As this was a community-based study, not all variables could be controlled, although the families' activity diaries suggested that their usual activities and therapies remained much the same during the course of the study. The participants also received a lot of one-to-one therapy time, and it is unknown whether this intensive attention would occur from other interventions.

CONCLUSION

This study provided evidence that the use of an adaptive bungee trampoline, with appropriate supervision, could be an enjoyable therapeutic alternative to achieve goal-related improvements in lower limb muscle strength and functional mobility for children with various functional classifications, provided that the children are appropriately screened and monitored during the intervention. Despite the suggestion that trampolining could potentially alter tone as a result of increased sensory feedback,[10] there were no adverse effects on muscle length and spasticity, as monitored each week, nor complaints of pain from the bungee trampoline program. Monitoring muscle length and spasticity is still recommended for future trampolining programs. Participants had high adherence to the program and reported high self-rated enjoyment. These results may contribute to an overall increased participation in PA, as well as the therapeutic benefits that occurred. Future research should further investigate the feasibility of the adaptive bungee trampoline using a larger sample of children with CP to improve generalizability.

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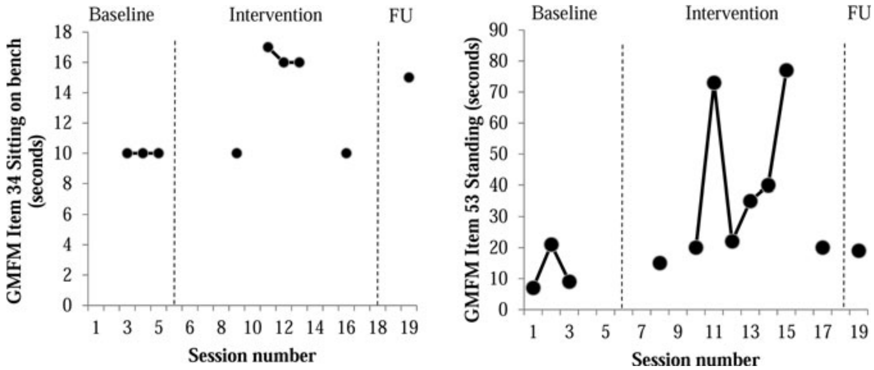

Fig. 5. Weekly goal-related results for participant 4. Discontinuous lines indicate missing data for this participant.

TABLE 3
Outcome Measures[a]

	Baseline Mean (SD)	Intervention Mean (SD)	Follow-up	Visual Analysis	2SD Method	PND, %	SMD
Participant 1							
Left ankle plantar flexors strength, lb	28.6 (4.7)	30.4 (5.7)	59.4			0	0.4
Right ankle plantar flexors strength, lb	34.8 (6.3)	32.1 (6.4)	35.2			0	− 0.4
Left quadriceps strength, lb	30.4 (3.2)	36.7 (10.6)	52.8	√	√	30	1.9[b]
Right quadriceps strength, lb[c]	34.3 (6.5)	35.2 (8.5)	44.0	√		10	0.1
Left hip abductors strength, lb	45.3 (3.0)	44.2 (6.8)	55.0			20	− 0.4
Right hip abductors strength, lb	46.2 (3.8)	57.9 (11.4)	70.4	√	√	70	3.1[b]
Left hip extensors strength, lb	53.7 (13.3)	63.8 (16.3)	61.6			10	0.8[b]
Right hip extensors strength, lb	56.4 (4.9)	60.5 (19.4)	66.0	√	√	50	0.8[b]
Functional strength	44.0 (2.9)	42.8 (5.8)	32.0			10	− 0.4
Left heel raises	2.2 (0.8)	5.5 (2.3)	2.0	√	√	90	3.9[b]
Right heel raises	4.0 (1.6)	5.2 (1.9)	3.0	√		20	0.8[b]
Left single-limb stance, s	3.3 (3.8)	2.6 (0.8)	2.9			0	− 1.5
Right single-limb stance, s	1.7 (0.4)	3.4 (1.5)	3.6	√	√	70	3.7[b]
Participant 2							
Right ankle plantar flexors strength, lb	22.9 (5.3)	43.8 (11.2)	37.4	√	√	90.9[c]	3.9[b]
Right ankle dorsiflexors strength, lb	29.5 (3.3)	40.6 (11.1)	44.0	√	√	54.5	3.3[b]
Right hip abductors strength, lb	38.3 (4.3)	66.4 (12.2)	79.2	√	√	90.9[c]	6.6[b]
Timed Up and Go, s	4.7 (0.4)	3.8 (0.2)	4.0	√	√	100[c]	− 2.3
2-min walk test, m/sec	1.7 (0.5)	1.5 (0.1)	1.6			0	− 0.3
Functional strength	66.4 (10.5)	82.3 (17.2)	101.0	√	√	27.3	1.5[b]
Right heel raises	1.8 (0.8)	7.5 (5.0)	10.0	√	√	81.8[c]	6.9[b]
Right single-limb stance, s	7.9 (3.3)	18.3 (10.5)	92.0	√	√	72.7[c]	3.1[b]
Participant 3							
Left quadriceps strength, lb	17.6 (10.3)	27.6 (8.3)	35.2	√		54.5	1.0[b]
Right quadriceps strength, lb	18.9 (11.3)	29.2 (8.9)	35.2	√		45.5	0.9[b]
Left hip abductors strength, lb	26.4 (4.7)	39.0 (13.8)	61.6	√	√	54.5	2.7[b]
Right hip abductors strength, lb	22.0 (4.4)	44.3 (16.5)	70.4	√	√	90.9[c]	5.1[b]
Left hip extensors strength, lb	18.0 (6.5)	23.2 (4.7)	35.2	√		36.7	0.8[b]
Right hip extensors strength, lb	17.8 (2.6)	29.4 (12.5)	44.0	√	√	63.6	4.6[b]
Functional strength, lb	14.4 (3.4)	17.3 (3.3)	19.0	√	√	36.7	0.8[b]
Timed Up and Go, s	8.0 (0.7)	7.2 (0.5)	7.3			18.2	− 1.1
Participant 4							
Modified GMFM item 34, sitting on bench, s	10.0 (0.0)	13.8 (3.2)	15.0	√	√	60	[d]
Modified GMFM item 53, standing, s	12.3 (7.6)	37.8 (23.7)	19.0	√	√	75[c]	3.4

Abbreviations: GMFM, Gross Motor Function Measure; PND, percentage of nonoverlapping data; SD, standard deviation; SMD, standard mean difference; 2SD method, 2-standard deviation band method.
[a]No standard deviations are recorded for follow-up as this assessment was a once-only measure.
[b]SMD greater than or equal to 0.8, indicating a large effect size.[25]
[c]PND greater than or equal to 70, indicating effective treatment.[25]
[d]SMD not calculated because baseline SD = 0.

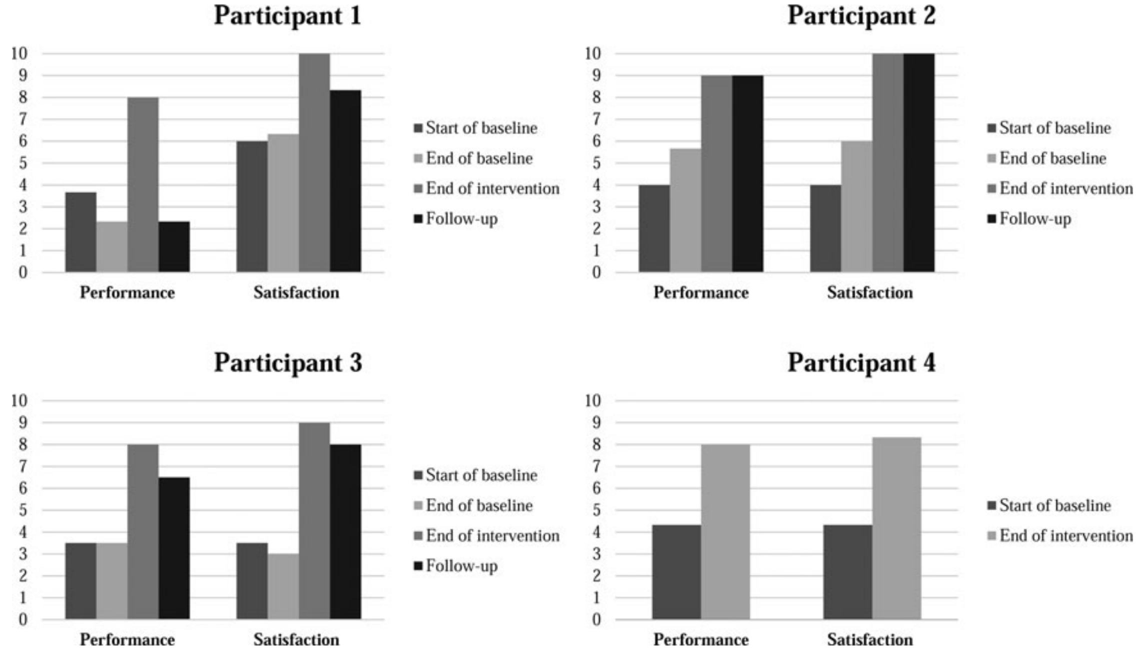

Fig. 6. Canadian Occupational Performance Measure.

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CLINICAL BOTTOM LINE

Commentary on "Effects of Adaptive Bungee Trampolining for Children With Cerebral Palsy: A Single-Subject Research Design"

"How can I apply this information?"

Children with neurodevelopmental disabilities experience higher levels of sedentary activity than peers with typical development which can increase risk for multisystem negative health outcomes.[1] Providing enjoyable options for children to increase their activity levels is important in developing lifelong fitness behaviors and improving long-term health.[2] This investigation demonstrates effective use of individualized and clinically meaningful outcome assessments that could be easily replicated in most clinical settings. It also provides an example of how intervention provided at a higher frequency and intensity level than traditional therapy can be feasible, effective, and enjoyable for families and children. The results of this study offer initial evidence that may support the use of trampolining as an intervention to increase the activity level of children across functional levels that is enjoyable.

"What should I be mindful about when applying this information?"

The results of this study are not generalizable to the larger population of children with cerebral palsy due to the small number of participants and difficulty in accessing an adaptive trampolining system. Interventions for children with neurodevelopmental disability are most effective when they are task specific, directly related to a child and family's goals, and specifically dosed to access the plasticity of targeted systems.[3] While participants increased their activity levels, interventions in this study may not have been dosed specifically enough to consistently induce systemic changes needed for long-term functional changes. Individual participants' outcome assessments should be interpreted with caution as information regarding minimal detectable change or minimal clinically important difference was not reported except for the Canadian Occupational Performance Measure. This information allows for improved understanding of the size and significance of changes over time. Evidence that adaptive trampolining may be an option to increase intensity of activity for children with cerebral palsy that is enjoyable has promise and should be further explored with a larger sample size.

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