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Feasibility of motor capability training at home in children with acquired brain injury

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Abstract

Objectives Acquired brain injury (ABI) requires an extended recovery time and residual signs may be observed years after discharge. Supervised home-based motor training may present a viable option for continuing treatment of adult patients, but little information is available on home-based treatment in children. This study assessed the feasibility of home practice in children with ABI (1 or more years post-trauma). The efficacy of the programme was also evaluated.

Design A non-randomised, self-control study with control and intervention periods.

Setting Home-based exercise programme.

Participants Nineteen children (mean age 12.5 ± 3.1 years).

Interventions A 4-week daily training programme of step-up and sit-stand-sit exercises.

Main outcome measures Feasibility was assessed by the number of participants who completed the programme. Efficacy was evaluated at different stages using 10-metre walking and 2-minute walking tests, and the balance subitems of the Bruininks-Oseretsky Test of Motor Proficiency. An energy expenditure index was calculated for walking. Performance scores were used to assess balance.

Results Nine participants completed the study. The mean number of training sessions was 22 ± 8 of the 30 sessions originally scheduled. Major differences were noted between the experimental stages. Walking speed, endurance and balance improved significantly during the intervention period.

Conclusions Continuing exercising at home may be a feasible and efficient option for a considerable proportion of ABI children who are compliant with a simple but challenging exercise programme. A randomised controlled trial with a larger sample is now required.

Keywords: Feasibility; Acquired brain injury; Home-based practice; Children

Introduction

Acquired brain injury (ABI) is a general categorisation describing any sudden non-progressive injury to the brain that occurs as a result of trauma (e.g. head injuries after traffic accidents, falls or anoxia after drowning) or because of a non-traumatic pathology (e.g. stroke, brain tumours, infections). It is the most common cause of morbidity and mortality in children and young adults [1].

Several studies have reported long-lasting deficits in the motor proficiency of children after ABI, leading to significant functional damage. The majority of children sustaining severe brain injury regain independent ambulation, but balance and speed frequently remain impaired [2,3]. Rossi and Sullivan found deficits in strength, agility and co-ordination 4 years after the damage, which limited the children's participation in sports and other physical activities [4]. Chaplin *et al.* documented the physical performance of a group of children with traumatic brain injury 16 months following the injury using the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) [5]. They showed that gross motor skills requiring speed, balance, strength and bilateral co-ordination were significantly affected. These authors also showed that when speed was a component of either fine or gross motor tasks, a pattern of significant differences was found compared

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with healthy controls [6]. Evidence also shows that children with ABI use more energy during motor activity than healthy controls [7].

Empirical evidence [8,9] suggests that strength training after discharge, using intensive task-specific training protocols, may help to maintain exercise capacity and may even improve the level of motor skill in children with cerebral palsy (CP). Similarly, repeated practice of simple exercises, such as sit-to-stand exercises [10,11], step-up exercises [11], ergometric bicycle riding [12,13], mechanical stepper and/or circuit training [14], in adults after suffering brain injuries or stroke induces similar gains in motor skill such as gait velocity and balance, and exercise capacity.

Evidence of the beneficial effects of home-based programmes on motor function has been presented for post-stroke or post-traumatic brain-injured adults using task-specific exercises [11,15]. However, no systematic research has been undertaken on the feasibility and efficacy of such programmes in children. Only a few studies have addressed adherence to such programmes. Dodd *et al.* [9] investigated the effects of a 6-week home-based strength-training programme in young patients with CP. On average, the participants completed 16.8 ± 2 out of 18 pre-scheduled sessions. On the other hand, Fragala-Pinkham *et al.* [16] reported a low adherence rate (33%) for a home-based fitness programme in nine children with motor disabilities.

The present study attempted to assess whether a simple home-based exercise programme represents a feasible therapeutic option in children with ABI (1 or more years post-trauma). The study also explored the extent to which home-based practice induces positive changes in selected motor functions that are shared by many activities of daily living. This is a preliminary study, and one of its aims was to provide data that may enable the calculation of statistical power in subsequent experimental trials.

Method

Experimental design

The study was based on a non-randomised self-control experimental design with repeated measures on three measurement sessions. The control period was taken as the period of time between the baseline and pre-training evaluations, while the intervention period was defined as the time between the pre-training and post-training evaluations. The experimental design is shown schematically in Fig. 1.

Participants

The sample of participants considered for the present study was composed of children who were hospitalised as a result of ABI in the Children Rehabilitation Department, Sheba Hospital, Tel-Aviv, Israel. Children were recruited from the outpatient clinic. An invitation letter to participate in the study

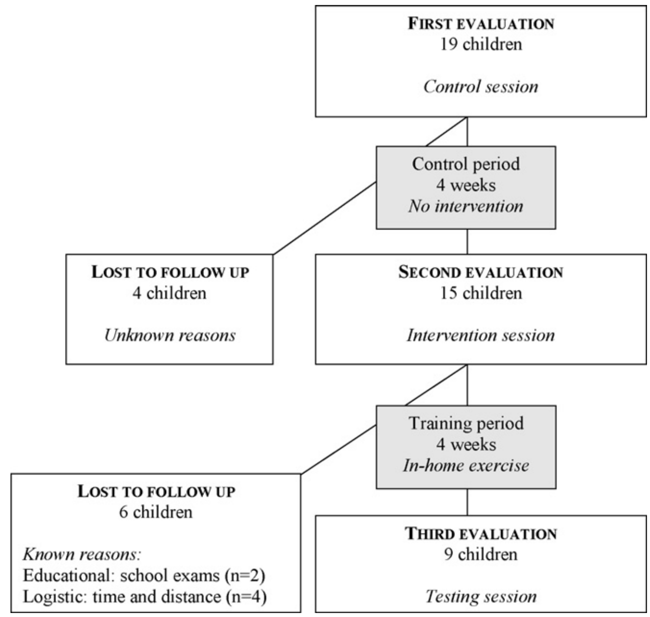

Fig. 1. Flow diagram of the experimental design used and the sample of subjects at each stage of the study.

was issued to all families and children who could potentially fulfill the following inclusion criteria.

(1) Age at the time of the injury: 5–15 years.
(2) Severity of head injury: as defined by a coma-state duration more than 6 hours after ABI, and a score equal to or less than 8 on the Glasgow Coma Scale [1].
(3) Date from the time of injury: children who were 1 or more years post-injury.

Informed consent was obtained from both parents prior to the initiation of assessments.

Measurement tools

Feasibility of the home-based programme was evaluated by the number of participants who adhered to all experimental stages (i.e. from the pre- to the post-training follow-up stage), and by the number of training sessions in which the participant completed the exercise protocols. Every child was provided with a diary where he/she was requested to keep a daily record of practice under supervision of the parents. This included exercises that were performed within a training day, the number of sets of each exercise and the number of repetitions in each set.

The effectiveness of the programme was evaluated by assessing the following.

(1) The mean walking speed was measured by manually timing the duration of an unconstrained 10-metre walk. Measurements were made within the mid-range of a 14-metre-long walkway [17].
(2) A 2-minute walking test was carried out within a 50-metre circular walkway [18]. The distance covered in

the 2-minute time interval was used as an estimate of cardiopulmonary and musculoskeletal endurance.

(3) The energy expenditure index was used as a relative estimate of metabolic energy expenditure. It was obtained from the difference between the steady-state heart rate at rest and the walking heart rate over the mean walking velocity. Heart rate was obtained using a wireless heart rate monitoring device (Polar Inc., Kempele, Finland). Resting heart rate was assessed while participants sat for 5 minutes. Walking heart rate was obtained after participants walked continuously for 2 minutes [19].

(4) Balance performance was assessed using the balance subitems of the BOTMP [5].

(5) The Box and Blocks test was used to evaluate hand motor function in an untrained manual skill (reach, grasp and transport a small object with the hand). This test was carried out to determine whether changes in target motor performances were indeed attributed to the specific lower-limb training, or merely to the fact that the children trained at home. This test of dexterity requires subjects to move a maximal number of small wooden blocks from one side to another side of a box within a period of 1 minute [20]. The number of blocks moved is the test score.

(6) The Paediatric Evaluation of Disability Inventory (PEDI) was used to describe the child's functional motor performance within the mobility and the self-care domains [21].

Procedures

Nineteen children with ABI and their parents arrived for the first meeting and were enrolled into the programme. Children underwent a general check-up by a paediatrician, which confirmed that they were able to participate in the exercise programme. A certified physical therapist with more than 17 years of clinical experience in paediatrics documented participation, provided instructions on the exercise programme and performed the motor assessments.

In order to test the efficacy of a home-based programme, simple but specific exercises that could be transferred to general motor actions (walking and maintaining erect standing balance) were implemented. The choice of the exercises was based on findings reported in previous studies showing that post-traumatic brain injury and adult stroke patients benefit from such exercises at home [11–14]. The two types of exercise selected for practice were sit-stand-sit and step-up exercises.

The first visit to the clinic was for a preliminary evaluation. The second visit was for a pre-training evaluation, where children and parents were exposed to the training protocol. The participants were given a practice period under the supervision of the therapist in the clinic. In this meeting, the number of repetitions per exercise was determined individually, i.e. the baseline ability. Throughout the meeting, parents were passive observers, although they were also expected to learn 'incidentally' the exercise protocol and the procedures.

Table 1
Descriptive information at entry time for the participant and dropout groups

	Participant group, $n=9$	Dropout group, $n=10$	*P*-value
Gender			
Male	5	4	0.490
Female	4	6	
Age (years)	13.6 ± 3.1 (8 to 16)	10.6 ± 3.7 (8 to 16)	0.290
Cause of injury			
Traumatic	3	7	0.180
Blood vessels	4	2	
Drowning	1	0	
Tumour	1	1	
Time post-injury (years)	2.7 ± 1.7 (1 to 5)	2.6 ± 1.1 (1 to 4)	0.790
Walking velocity (metres/second)	1.1 ± 0.2	1.4 ± 0.2	0.008[a]
Two-minute walk test (metres)	168.2 ± 33.7	189.7 ± 26.7	0.360
Energy expenditure index (beats/metre)[b]	0.92 ± 0.21	0.66 ± 0.11	0.040[a]
Bruininks-Oseretsky Test of Motor Proficiency			
One leg test on floor (seconds)	6.7 ± 3.5	9.5 ± 1.0	0.400
One leg test on balance beam (seconds)	7.5 ± 3.4	9.1 ± 1.5	0.780
Standing on one leg, eyes closed (seconds)	3.9 ± 3.6	6.7 ± 2.7	0.400
Walk forward on floor (no. of steps)	5.2 ± 1.0	5.5 ± 1.0	0.120
Walk forward on balance beam (no. of steps)	4.8 ± 1.4	5.3 ± 1.3	0.200
Walk heel–toe on floor (no. of steps)	4.7 ± 1.3	5.4 ± 1.2	0.120
Walk heel–toe on balance beam (no. of steps)	4.3 ± 1.5	5.2 ± 1.3	0.200
Steps over a stick (no. of steps)	0.5 ± 0.7	1.1 ± 0.7	0.110
Box and Blocks test with dominant hand (no. of blocks)	50.8 ± 13.3	53.4 ± 9.1	0.320
Box and Blocks text with non-dominant hand (no. of blocks)	31.7 ± 19.3	42.0 ± 17.1	0.150

Values are mean ± standard deviation (range).
[a] Significant.
[b] Energy expenditure index in beats/metre is a relative measure derived from (beats/minute)/(metres/minute).

At least one of the parents was assumed to be able to aid the child at home. Every participant was provided with a booklet that included graphic displays of the exercises.

Thereafter, participants were requested to perform the exercises over the 4-week intervention period under the supervision of one of their parents. They were instructed to exercise every possible day (three sets of sit-stand-sit exercises and three sets of step-up exercises with each leg daily, at least three times a week). The number of repetitions during the first 2 weeks was set at 60% of the individual maximal performance estimated during the pre-training measurement session, and up to 80% during the third and fourth weeks. The child was instructed to rest for 1 minute between sets [10]. For the sit-to-stand task, the seat height was adjusted to knee level. The step height for stepping exercises was 0.17 metres for all children. Every child was provided with a diary in which he/she was requested to keep a record of the number of sets and repetitions completed daily.

At a third visit, post-training measurements were recorded. In this last visit, the number of repetitions was counted for each practiced exercise. This number was used as the final measure of motor ability.

Data analysis

In order to determine any baseline differences between children who completed the study, i.e. the participant group, and children who dropped out of the study, i.e. the dropout group, the two groups were compared on the basis of the pre-entry baseline characteristics. Demographic and medical data are shown in Table 1. Frequency distributions were used to describe categorical data. Means and standard deviations were calculated for continuous variables. Differences between the participant and dropout groups were assessed using Student's *t*-test for the continuous variables and Chi-squared test for the categorical variables.

The intervention effects on walking and balance abilities were evaluated by calculating individual 'difference' scores for the control and intervention periods. The differences between scores were tested using Wilcoxon Signed Ranks test. Results were considered to be statistically significant at a confidence level of $P \leq 0.05$. Data were analysed using Statistical Package for the Social Sciences, Version 12 (SPSS Inc., Chicago, IL, USA) [22].

Table 2
Medians and interquartile ranges for sit-stand-sit and step-up exercises before and after training

	Before training	After training	*P*-value[a]
Sit-stand-sit (no.)	28 (19.5 to 30.5)	31 (27 to 49)	0.01
Step-up, right (no.)	30 (23.5 to 35.5)	41 (36 to 48)	0.03
Step-up, left (no.)	30 (26.5 to 41.5)	39 (31 to 48.5)	0.01

[a] Wilcoxon Signed Ranks test.

Results

The original sample that was enrolled for the experiment consisted of 9 boys and 10 girls (mean age 12.5 ± 3.1 years, range 8–16 years).

Ten of the participants (53%) suffered from the effects of a traumatic brain injury. The average time post-event was 3.0 ± 1.3 years. The mean PEDI mobility and self-care subscores were 58.1 ± 2.0 and 71.8 ± 2.0, respectively.

Of the 19 children enrolled in the study, only nine children completed both the control and intervention phases. There were no significant baseline differences between children in the participant and dropout groups. An exception was that children in the dropout group walked faster on average, with a significantly lower mean energy expenditure index compared with children in the participant group. None of the 10 children who withdrew from the study reported any difficulties or complications related to the prescribed training programme. Logistics were cited most as the most significant factor.

As reported in their exercise diaries, patients in the participant group exercised continuously for an average of 22 ± 8 training days within the 4-week period of practice at home. That is, participants who completed all sessions did not train

Table 3
Medians and interquartile ranges of walking and balance performance differences in the control and intervention periods

Difference scores	Control phases	Intervention phases	*P*-value[a]
Walking velocity (metres/second)	−0.06 (−0.13 to 0.07)	0.31 (0.18 to 0.48)	0.01
Two-minute walk test (metres)	−1.00 (−12.0 to 4.50)	26.00 (2.50 to 40.50)	0.02
Energy expenditure index (beats/metre)	0.12 (−0.2 to 0.34)	−0.25 (−0.62 to 0.01)	0.20
One leg test on floor (seconds)	0.0 (0 to 1)	1.0 (0 to 4.5)	0.24
One leg test on balance beam (seconds)	0.0 (−1 to 0)	1.0 (0 to 5)	0.02
One leg standing, eyes closed (seconds)	0.0 (0.5 to 0)	1.0 (0.25 to 2.0)	0.03
Walk forward on floor (no. of steps)	0.0 (0 to 0)	1.0 (0 to 1)	0.15
Walk forward on balance beam (no. of steps)	0.0 (0 to 0)	0.0 (0 to 1)	0.25
Walk heel–toe on floor (no. of steps)	0.0 (0 to 0.5)	1.0 (0.5 to 2)	0.02
Walk heel–toe on balance beam (no. of steps)	0.0 (0 to 0)	1.0 (0 to 2.5)	0.15
Stepping over a stick (no. of steps)	0.0 (0 to 0)	1.0 (0 to 2)	0.03
Box and Blocks test with dominant hand (no. of blocks)	2.0 (−2.0 to 9.0)	1.0 (−4.0 to 7.0)	0.33
Box and Blocks test with non-dominant hand (no. of blocks)	−2.0 (−7.5 to 5.5)	2 (−3.5 to 5.5)	0.51

[a] *P*-values for Wilcoxon Signed Ranks test for differences between phases.

for an equal number of days. However, all but one subject completed the minimal number of three training days per week. In addition, the average number of repetitions per training day varied between 26.6 ± 7 repetitions for sit-stand-sit exercises (range 20–40 repetitions) and 22.0 ± 9 repetitions for step-up exercises (range 10–35 repetitions). This was because relative levels of effort were defined at 60% or 80%, which implied that each individual achieved the appropriate level of heart rate (calculated previously in the clinic for every individual) with a different number of repetitions. Nevertheless, after 4 weeks of training, children in the participant group showed significant improvements in both sit-stand-sit ($P<0.05$) and step-up exercises ($P<0.05$) (Table 2).

Table 3 shows the results of the tests at different experimental stages for the participant group. Within-group comparisons using the differences between the outcome measures at subsequent evaluation periods as dependent variables showed significant improvements in walking speed (baseline − pre-training difference = −0.06 metres/s and pre-training − post-training difference = 0.31 metres/s; $P=0.01$) and in the 2-minute walking distance (baseline − pre-training difference = −1 metre and pre-training − post-training difference = 26 metres; $P=0.02$), as well as improvements in some items of the balance tests.

Discussion

The current study provides insights into whether it is practical to implement home-based training for children suffering from ABI. The study shows additional empirical evidence for the beneficial effects of such a home-based approach using simple exercises.

Feasibility and adherence to home rehabilitation programmes in children with ABI

The first finding of this study was that less than 50% of children with ABI and their parents succeeded in completing the training period. The specific exercises used in this study were chosen and designed to be short and simple enough to allow brain-injured individuals to participate, even if they suffered cognitive impairments. Thus, the high dropout rate may be associated with factors other than length of the protocol or complexity of the exercises. Follow-up testing locations, costs, frequency and duration of the protocols may influence adherence to home-based programmes. For example, some of the children and their parents in the present programme reported that the travelling distance for the periodic tests (from home to hospital and back) was a major reason for abandoning the programme. About 70% of the dropout group were children with post-traumatic brain injury. The socio–economic status of their families was not evaluated in the study, but social status and incidence of traumatic injuries are correlated [23]. Parents with a lower socio–economic status may be less compliant with scheduled appointments due to time and distance demands.

It should be mentioned that a significant proportion of the subjects were motivated to perform exercises at home without therapist supervision, with the encouragement and supervision of their parents. However, other subjects were not sufficiently motivated, or simply had no parental support for adherence to such programmes (e.g. because of the periodic testing). It is not possible to determine at this point if motivation was a key factor underlying adherence, as motivation was not tested in this study. However, in light of other studies [9,16], it may be argued that such a factor is indeed very important. Taylor *et al.* [24] reported that adherence to a strength-training programme composed of simple exercises in CP children was influenced by factors such as support of family members (primarily parents), as well as availability of equipment, simplicity of the programme and the role of the therapist as coach. On the other hand, adherence to such a programme was influenced by individual motivation, by a sense of autonomy, and by the efforts made to achieve the goals of the programme [24]. The authors interpret the latter as an indication of how challenging the exercise programme is for the participant. The specific exercises used here were simple enough to enable participation of children with ABI [11]. However, it may be argued that the high rate of dropout was associated with the perception of some children that the exercises did not provide a challenging experience. In fact, subjects who dropped out early in the programme outperformed their counterparts at the start of the programme, and thus, the proposed exercise protocol might have been perceived as ‘too easy’. Such a possibility should be considered in the future, although the parents and/or children who abandoned this programme provided no explicit explanations. Therefore, home-based exercise programmes should be constructed to satisfy individual needs in ways that challenge the child’s capabilities continuously.

Beneficial effects of practicing task-oriented exercises

An additional finding of this study was that children who succeeded in completing the training period showed significant improvements in walking and balance performances, regardless of whether or not they trained daily. However, manual motor skills that were not practiced during the training sessions, such as hand grasping actions, did not improve. In other words, practice at home under the supervision of parents *per se* had no general effects on unpracticed motor performances, while performing simple lower limb exercises at home did have an effect.

A critical issue for rehabilitation is how to build a specific training programme. First, any such programme should be expected to allow for a positive transfer from the practiced tasks at home to the common activities of daily living. The amount of this transfer may depend on the similarity between tasks or environments [25–27]. Step-up exercises [28] and the Timed Up and Go test [29] are common means for assessment of balance in adult patients with motor impairments. The training protocol incorporated similar motor elements to those involved in these tests. Thus, as a natural result of practicing the step-up and sit-stand-sit tasks, walking and balance improved as they share some biomechanical characteristics.

It is worth mentioning that at the end of the intervention period, five children asked to continue the programme, three others mentioned that they were more active in sporting activities with friends following the post-training session, and another child adopted long-distance walks as a daily exercise routine.

Limitations of the present study and suggestions for future research

The first drawback of the present study is that not all of the personnel who collected data were 'blind' to the home training protocols and the subjects. The second major limitation of the present study is the small number of participants who started and completed the trials.

Regarding the first issue, the authors believe that this did not have a major influence on the present preliminary findings. Unpublished video-based data on playback assessments that were carried out by two additional physical therapists showed that the three therapists agreed independently on most of the changes observed using a movement quality visual assessment scale. Nevertheless, in the future, it is suggested that findings should be re-inforced using a double-blind experimental design with more than one person assessing the performance of children at the different stages of the experiment.

The findings regarding the large dropout percentage may be important. The sample was eventually reduced, and among the participants, there were variations in the total number of training days (9–28 days), age (8–16 years), the spectrum of the post-injury period (1–5 years) and the ABI aetiology. However, these factors have no detrimental effect on the interpretation of the results because the findings correspond to those of similar studies based on small numbers of participants (e.g. [20]). In fact, it may be argued that gains in performance from one training stage to another are encouraging because the statistically significant differences found in the present study were observed in spite of the large variance inherent in any clinical neurological population and in spite of the small sample size.

In the future, a larger sample of participants is needed to strengthen these findings. According to the results, the necessary sample-size based on the walking velocity outcome is 32 children (type-one error $\alpha = 0.05$, power of the test $\beta = 0.8$). In addition, a randomised controlled trial is needed to re-inforce these findings. A third stage of follow-up could enable an assessment of long-term implications of home-based programmes.

Further attention should be dedicated to investigate motivational and psychosocial characteristics of participants and their families (e.g. socio-economic status) who tend to drop out from such programmes. Characteristics of individuals who comply fully with exercise protocols at home should also be investigated more specifically. The effects of treatment at home could be even more beneficial if social interaction between peers is encouraged (i.e. training at home with one or more peers). Finally, these results have some implications for motor rehabilitation. They demonstrate that children with ABI may improve and reach near-normal values if they are encouraged to follow short but intensive task-specific training programmes.

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Conflicts of interest: None.

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