Article

CLINICAL REHABILITATION

Clinical Rehabilitation
27(10) 939–947

DOI: 10.1177/0269215513485591
cre.sagepub.com
SAGE

Effects of a predefined mini-trampoline training programme on balance, mobility and activities of daily living after stroke: a randomized controlled pilot study

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Abstract

Objective: To investigate the effects of a predefined mini-trampoline therapy programme for increasing postural control, mobility and the ability to perform activities of daily living after stroke.
Design: Randomized non-blinded controlled pilot study.
Setting: Neurological rehabilitation hospital.
Subjects: First-time stroke; age 18–80 years; independent standing ability for a minimum of 2 minutes.
Intervention: Patients were randomized into two groups: the mini-trampoline group (n = 20) received 10 sessions of balance training using the mini-trampoline over three weeks. The patients of the control group (n =20) participated 10 times in a group balance training also over three weeks.
Main measures: Postural control (Berg Balance Scale, BBS), mobility and gait endurance (timed 'up and go' test, TUG; 6-minute walk test, 6MWT) and the ability to perform activities of daily living (Barthel Index, BI). Measurements were undertaken prior to and after the intervention period.
Results: Both groups were comparable before the study. The mini-trampoline group improved significantly more in the BBS (P = 0.003) compared to the control group. Mean or median differences of both groups showed improvements in the TUG 10.12 seconds/7.23 seconds, the 6MWT 135 m/75 m and the BI 20 points/13 points for the mini-trampoline and control group, respectively. These outcome measurements did not differ significantly between the two groups.
Conclusion: A predefined mini-trampoline training programme resulted in significantly increased postural control in stroke patients compared to balance training in a group. Although not statistically significant, the mini-trampoline training group showed increased improvement in mobility and activities of daily living. These differences could have been statistically significant if we had investigated more patients (i.e. a total sample of 84 patients for the TUG, 98 patients for the 6MWT, and 186 patients for the BI).

Keywords

Balance training, postural control, rehabilitation, stroke, trampoline

Received: 18 August 2012; accepted: 16 March 2013

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Introduction

The ability to control balance in the sitting and standing positions after a stroke is a fundamental skill of motor behaviour that allows autonomy in everyday activities.[1] Like any other motor skill learned by the central nervous system (CNS), postural control strategies can become more efficient and effective with training and practice.[2] A number of diverse physiotherapy approaches have been developed on the basis of different ideas about how people recover from a stroke. Pollock et al.[3] reviewed several approaches and found no evidence that one was clearly better than another in improving leg strength, balance, walking speed or the ability to perform everyday tasks. They recommend that future research should concentrate on investigating the effectiveness of clearly described individual techniques and task-specific treatments, regardless of their historical or philosophical origin.

Exercises on a mini-trampoline consist of a multi-component approach involving strength and balance training, physical fitness, body stability, muscle coordinative responses, joint movement amplitudes and spatial orientation. Aragão et al.[4] investigated whether a 14-week mini-trampoline training contributes to improvements of dynamic stability performance in elderly subjects. They reported more improvement of plantarflexor muscle strength (~10%) and the ability to regain balance during forward falls. This regaining of balance was associated with a higher rate of hip moment generation after perturbation. Some studies on patients with orthopaedic disorders have already shown that a mini-trampoline training is an effective method for improving balance after ankle distortions[5] or in general for improving balance and strength. It also was successful in equalizing muscular imbalances between the two limbs.[6] Moreover, Erichsen and Böttcher[7] reported improvements in the standing balance and movement coordination of more than 20 brain-injured children or adolescents with hemiparesis or tetraparesis after trampoline training. They emphasized its usefulness in medical rehabilitation treatment and its positive psychological effect.

However, there are only a few studies examining the effects of a trampoline training programme. Although patients with a hemiparesis have been included, diagnosis is limited to traumatic brain injuries. No study has addressed the potential to use a mini-trampoline training programme in a stroke population.

The purpose of this randomized controlled pilot feasibility study was to evaluate the effects of a predefined three-week mini-trampoline training programme on postural control, mobility, gait endurance and the ability to perform activities of daily living after stroke compared to balance training in a group, and if not statistically significant to allow for calculation of the sample size of further studies. We hypothesized that training on a mini-trampoline would lead to better outcome than standard balance training in a group.

Methods

This study was conducted between July 2008 and August 2009. Patients of the Neurologische Klinik Bad Neustadt/Saale who participated in the study had a hemiparesis as a result of a first-time stroke. All met the following inclusion criteria: age 18–80 years; ability to stand for a minimum duration of 2 minutes and to walk with or without walking aids, including foot splints; a body weight <120 kg; sufficient cardiopulmonary capacity; ability to understand the therapy instructions.

After signing a written informed consent form, patients were randomly allocated to one of the two intervention groups by a person not involved in any other part of the study. Sealed opaque envelopes were consecutively drawn to assign patients to their specific intervention and every allocation was documented on a randomization list. The study was approved by the institutional ethics committee.

The mini-trampoline group received ten 30-minute sessions of training on a mini-trampoline (Funhop, Bremshey-Sport, 125 cm diameter) over a period of three weeks.

The mini-trampoline was placed in the corner of a room, with a therapy bench on the third side. A therapist stood on the fourth side to protect the patient from falling.

The therapists were trained in a half-hour session to become familiar with the predefined 15-task therapy programme. The following exercises were performed:

1. Shifting weight while standing (sway in each of four directions: forward, backward, right, left)
   a) with feet at the same level
   b) with feet in a walking stance (variation: right or left foot in front)
2. Lifting heels (alternately right/ left)
3. Bouncing without predetermined position of the feet
4. Bouncing with feet in a walking stance (variation: right or left foot in front)
5. Bouncing with feet together
6. Walking stance, one supporting leg, alternately steps to the front and to the back of opposite leg (variation: change supporting leg)
7. Walking in place
8. Combining steps
9. Stepping while balancing objects (e.g. balloon on a badminton racket)
10. Tossing balloon between patient and therapist (varied passing angle)
11. Throwing ball between patient and therapist (varied passing angle)
12. Jumping in place
13. Jumping with feet together or with scissor steps (to the front, back, right, left)
14. Jumping combined with rotations around the longitudinal body axis
15. Jogging in place.

All tasks could be done with eyes open or closed, or in combination with a second cognitive task (e.g. counting backwards) to increase task difficulty. The decision was made by the therapists – guidelines were not determined. For therapy documentation see supplemental material (online).

The therapies were carried out according to the patients' capabilities. Patients were not allowed to hold on to anything, only to protect themselves from falling. Rest periods were permitted for as long as the patients needed.

The control group received ten 30-minute sessions of balance training in a group over a period of three weeks. The training was organized in two different therapy groups with consecutive functional levels. Assignment or a group change was adapted according to the patients' functional state or gain.

The balance training comprised task-related components which required posture in sitting and standing positions, and gait. This included step combinations (to the front, back, right, and left), gait variations or the use of sports equipment (i.e. rod, ball, cloth, rings, tyres, rope, balloon, step board). All training took place on a stable, firm surface. Resting in a seated position was permitted, but patients had to stay active while sitting (i.e. they were still integrated in the group activities). During control therapy the patient was not allowed to hold on to anything, only to protect him/herself from falling.

In addition, both groups received individualized physiotherapy and a comparable amount of the usual resource-oriented therapies.

The measurements were performed one day before the start (pretest) and one day after the termination (posttest) of the specific intervention. All tests took place in a separate room. The coordinating investigator, CM, and two physiotherapists at the neurological hospital evaluated all outcome variables, except for the Barthel Index. They were not involved in the treatment and not blind to the study conditions. The coordinating investigator had trained all assessors in workshops before the onset of the trial. The attending physician and nurses routinely assessed the Barthel Index together weekly. They were blind with respect to the group assignment and the study conditions.

Berg Balance Scale[8,9] (BBS, 0–56) is a performance-based assessment tool that is used to evaluate balance during functional activities. The patient performs 14 different tasks and receives a score ranging from 0 (cannot perform) to 4 (normal performance). Overall, added scores can range from 0 (severely impaired balance) to 56 (excellent balance). The BBS was the primary outcome measure.

The timed 'up and go' test (TUG)[10] measures, in seconds, the time taken by a patient to stand up from a standard armchair (seat height 46 cm), walk a distance of 3 m, turn, walk back to the chair and sit down.

The 6-minute walk test (6MWT)[11,12] requires a patient to walk as far as he or she can in 6 minutes and not to stop unless necessary; the total distance was measured. Patients were allowed to use their customary walking aids.

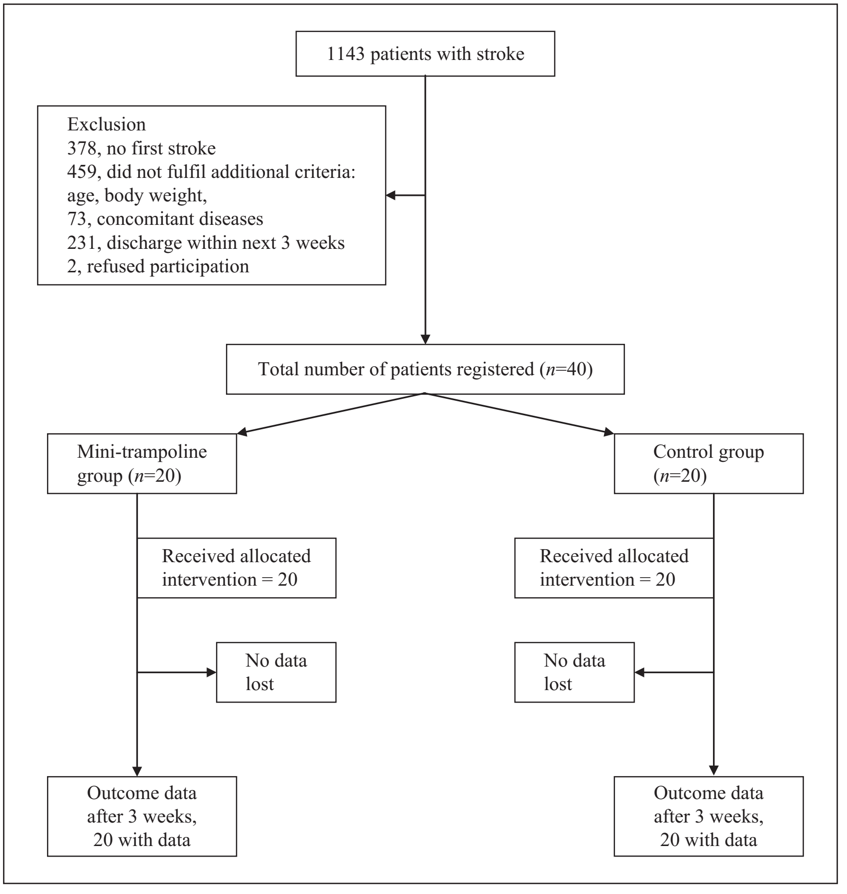

Figure 1. Patient flow through the study.

The Barthel Index[13,14] (BI, 0–100) was used to assess independence in activities of daily life; the German version of the BI was used.

Statistical analysis was performed using SPSS (Statistical Package for the Social Sciences) version 17.0. A difference was considered statistically significant if $P < 0.05$.

Student's *t*-test, Mann–Whitney *U*-test, and chi-square analyses were used when appropriate for comparisons of demographic and functional variables between the groups at pretest.

The BBS and BI were tested with non-parametric methods using the Wilcoxon matched pair test for estimating the changes from pretest to posttest. For comparisons between groups, intra-individual differences (ΔBBS, ΔBI) were calculated and analysed using the Mann–Whitney *U*-test.

TUG and 6MWT were analysed in a two-way repeated-measurement analysis of variance (ANOVA) with 'time of measures' (pretest versus posttest) as a within-subject factor and 'intervention' (mini-trampoline versus control group) as a between-subject factor.

Results

Forty patients were included into the study. All patients completed the training with their allocated intervention and all scheduled measurements (i.e. no data were missing). Figure 1 shows the flow of patients throughout the study.

Table 1. Patient characteristics.

	Mini-trampoline (n =20)	Control (n =20)	P-value
Age, years	58 (±11) (range: 36–78)	57 (±12) (range: 41–75)	0.767*
Sex (female/male)	7/13	8/12	1.000°
Diagnosis (ischaemia/ haemorrhage)	14/6	17/3	0.451°
Side of paresis (right/left)	9/11	12/8	0.527°
Time since stroke, months	9.8 (±19.1) (range: 0.4–75)	9.1 (±20.8) (range: 0.4–82.7)	0.914*

Values are mean ± standard deviation or number.
P-values were calculated using *t*-test (*) or chi-square test (°).

Table 2. Outcome measures for both intervention groups.

	Pretest	Posttest	Change scores
Berg Balance Scale (0–56), median (25% percentile–75% percentile)			
Mini-trampoline	39 (36–45)	53 (50–55)	12 (9–16)
Control	39 (35–46)	47 (42–52)	5 (3–11)
Timed 'up and go' test, seconds; mean ± standard deviation			
Mini-trampoline	24.4 (±13)	14.2 (±8)	10.12 (±8)
Control	28.7 (±15)	21.5 (±11)	7.23 (±11)
6-minute walk test, m; mean ± standard deviation			
Mini-trampoline	261 (±158)	396 (±261)	135 (±144)
Control	200 (±129)	275 (±201)	75 (±108)
Barthel Index (0–100), median (25% percentile–75% percentile)			
Mini-trampoline	55 (45–80)	85 (68–98)	20 (13–28)
Control	53 (45–75)	70 (58–90)	13 (5–23)

Table 1 shows patient characteristics for both intervention groups at the pretest. Table 2 shows the outcome parameters for both intervention groups at the pre- and posttest. Comparisons of demographic data and functional tests revealed no significant differences between the mini-trampoline and the control group before the intervention ($P > 0.188$).

Both groups exhibited a significant increase in their postural control and balance after three weeks of therapy ($P < 0.0004$, for both groups). The between-group analysis revealed significantly better intra-individual improvements in the mini-trampoline training group compared to the control group (ΔBBS: $U = 95.5$; $P = 0.004$). Because of the large variability of BBS baseline values an ancillary analysis was performed to look for a correlation between these BBS baseline values and the ΔBBS values. Analysis revealed a significant negative correlation ($r = –0.615$; $P < 0.0004$) (i.e. the lower the BBS baseline values, the higher the increase after the interventions). However, we had no limiting ceiling effect of the BBS. Only 4 patients (3 in mini-trampoline, 1 in control) achieved the maximum score.

The two-way repeated-measurement ANOVA for the TUG with the factors 'time of measure' and 'intervention' showed a significant time effect ($F_{1;38} = 32.746$; $P < 0.0004$; $\eta^2 = 0.463$), but no significant interaction was found ($F_{1;38} = 0.908$; $P = 0.347$;

$\eta^2 = 0.023$) and the differences between the groups were not statistically significant ($F_{1;38} = 2.846$; $P = 0.100$; $\eta^2 = 0.070$).

For the 6MWT the ANOVA showed the following results: a significant main effect for the factor 'time of measure' ($F_{1;38} = 27.295$; $P < 0.0004$; $\eta^2 = 0.418$), but no significant interaction ($F_{1;38} = 2.228$; $P = 0.144$; $\eta^2 = 0.055$) was found and the differences between the groups were not statistically significant ($F_{1;38} = 2.479$; $P = 0.124$; $\eta^2 = 0.061$).

Values for the Barthel Index in both groups increased significantly during the three weeks of therapy ($P < 0.0004$ for both groups), but there was no significant difference between the groups (ΔBI: $U = 147.5$; $P = 0.157$).

Both the mini-trampoline group and the control group significantly increased their mobility and walking endurance. Their performance of activities of daily living also rose to a higher functional level within the intervention phase. Although patients in the mini-trampoline group improved more, the differences were not statistically significant.

Therefore a sample size estimation for the TUG, 6MWT and BI was performed using *G**power 3.[15] Assuming that TUG and 6MWT are going to be analysed with a 2 × 2 repeated-measurement ANOVA, the eta-square values for the factor 'intervention' of the present study lead to the following sample size estimates: total sample size TUG: 84 patients; 6MWT: 98 patients. Assuming that BI is going to be analysed with a non-parametric test, the calculated effect size ($P_{Noether}$)[16] was 0.3675, which leads to a total sample size estimation of 186 patients.

Discussion

This is the first randomized controlled pilot study investigating the effects of a predefined mini-trampoline training programme for stroke patients compared to standard balance training in a group. We were able to verify our hypothesis that patients achieve a significant increase in balance control measured by the BBS. Although not statistically significant, mini-trampoline training also seems to have a positive effect on mobility, gait endurance and the ability to perform activities of daily living.

However, our study has certain limitations. First, the small sample size and the relatively short follow-up limit the generalizability of our findings and require that they be interpreted with caution. However this small population and the short duration were sufficient to find some statistically significant changes and clinically relevant improvements. Second, the assessors of the outcome variables were aware of which treatment was being given. Finally, the mini-trampoline training took place in a one-on-one therapy situation (individualized therapy situation), whereas the patients of the control group practised in small groups of up to 8 patients. Training in small groups is limited by the mean motor-functional level of all participants and is not mainly oriented to individual skills. Nevertheless, McNevin et al. reported that patients may learn successful strategies by watching other group participants and so enhance the effectiveness of their therapy.[17]

At the initial assessment both groups scored a median value of 39 (total score = 56) points on the BBS, indicating balance deficits in all participants. This is comparable to previous studies focusing on balance training with stroke patients.[18–20] However, after the intervention period participants in the mini-trampoline training group scored 52 points, clearly beyond the cut-off score of 45, which implies a lower risk of falls and a higher level of independent and safe mobility.[8,21] The score of the patients in the control group only rose to 47 points. In addition, differences of more than 6[22] or 8[23] points were described as real changes. This means our control group had a clinically relevant gain in balance control too, but the mini-trampoline training group increased twice as much.

The TUG and the 6MWT were used to determine enhancement in mobility and gait endurance. The BI was used to assess the influence of an increased balance control on the activities of daily living. The results of these outcome parameters showed that the mini-trampoline training group improved considerably compared to the control group, although the analysis did not show statistically significant differences between the two intervention groups.

Podsiadlo and Richardson[10] considered the TUG to be predictive for patients' independent walking ability. Participants who performed the TUG and required less than 20 seconds are regarded as independent in balance and mobility skills required for activities of daily living. In comparison, those who took 30 seconds or more were dependent for most activities of daily living and mobility skills.[24] The mini-trampoline training group achieved a mean 14 seconds and acquired clear gains in mobility, while the control group remained in the 'grey zone' of 21 seconds. A higher value of the 6MWT indicates a faster velocity and thus better mobility and balance ability. Studies suggest that an improvement on the 6MWT exceeding 13% is meaningful.[25] The mean difference of 135 m in the mini-trampoline group and 75 m in the control group corresponds to 52% and 38%, respectively. This represents clinically meaningful improvements in both groups. In addition, walking capacity as measured by means of the 6MWT is a strong predictor of community walking ability[26,27] and is associated with a higher quality of life.[28]

Aragão et al.[4] found that the 14 weeks of mini-trampoline training with elderly subjects improved their ability to regain balance during a sudden fall forward. The intervention group showed an important improvement in using the mechanism of dynamic stability (i.e. increase of base of support). In addition they reported more improvement of plantarflexor muscle strength (~10%). Loss of ankle range or strength limits a patient's ability to use an ankle strategy for postural control.[24] Increasing the rate of hip moment generation seemed to be the most important reason for the improvement of the mechanism of dynamic stability and determined a faster recovery step in the trained group after the mini-trampoline exercises.[4] Possible mechanisms for the positive results of our mini-trampoline training group may be caused by the continuous demand of remaining balanced on an elastic and unstable surface as a permanent reactive and adaptive training. It may result from a higher range in variability of postural responses. Because of permanent destabilization forces and increasing difficulty, the participant is challenged to stabilize single parts of the body while keeping the centre of mass over the base of support and responding to the demands of different tasks or environments. For balance to improve, participants have to exercise their muscle force and neuromuscular responses against an external resistance, as a consequence of voluntary movement, or in response to an unexpected perturbation, in order to maintain the body's centre of mass within manageable limits of the base of support or in transit to a new base of support.[29] In addition, repetitive jumps on an elastic surface lead to motor and perceptual changes in subsequent jumps on a stiff surface. Adaptation to an elastic surface led to an increase in leg stiffness and a decrease in jump height. These after-effects reflect adjustments in an internal model of the elastic surface that carries over into movements produced on the stiff surface.[30]

It is very important that the mini-trampoline training situation be as safe as possible. At the same time foot splints are, if necessary, advisable. Also, attention should be paid to a safe training area in compliance with the guidelines, for example, of the American Academy of Paediatrics.[31]

In our study, training on the mini-trampoline has shown to be a feasible and safe method (no adverse events occurred) further studies could investigate whether the mini-trampoline training programme could be a feasible, affordable and beneficial home self-training programme. In addition, further randomized controlled studies should consider using an elongated follow-up period to determine the long-term benefits or should define a control group receiving balance training on a dynamic ground, for example a balance board.

In conclusion, this pilot study showed that a predefined mini-trampoline training programme resulted in significantly increased postural control in stroke patients compared to balance training in a group. Mini-trampoline training also seems to have a positive effect on mobility, gait endurance and the ability to perform activities of daily living. Although not statistically significant, the mini-trampoline training group showed increased improvement in mobility and ADL. These differences could have been statistically significant if we had investigated more patients (i.e. a total sample of 84 patients for the TUG, 98 patients for the 6MWT, and 186 patients for the BI).

Clinical messages

- A predefined mini-trampoline training programme with stroke patients significantly increased their balance control compared to balance training in a group.
- Improvements in mobility and activities of daily living function were superior for the trampoline group.
- Up to 98 or 186 patients are needed to reveal statistically significant effects for mobility or activities of daily living function, respectively.

Acknowledgements

The authors would like to thank all participating patients. In addition they thank the physiotherapy team at the Neurologische Klinik Bad Neustadt/Saale, Germany, for their engagement, for their contribution to the process and for their support of this study, and J Benson for copyediting the manuscript.

Conflict of interest

The author declares that there is no conflict of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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