Improving Directional Control of the Upper Limb in Severe Stroke: Efficacy of the Bobath Concept: A Pilot Randomised Trial

Kim A. Brock *PhD, BPhysio*
Physiotherapy Department, St Vincent's Hospital, Melbourne, Australia

Carolyn Luke *MPhysio, BAppSc (Physio)*

Jane Tillyard *MPhysio (Neurological Physiotherapy), BPhysio*
Physiotherapy Department, Western Health, Melbourne, Australia

Janine Simondson *MAppSc, Grad DipPhysio*
Physiotherapy Department, St Vincent's Hospital, Melbourne, Australia

Susie Black *MPhysio, BPhysio*
Physiotherapy Department, St Vincent's Hospital, Melbourne, Australia

ABSTRACT

This study investigated whether a brief intervention based on the Bobath concept in people with severe stroke receiving inpatient rehabilitation resulted in enhanced directional control of the upper limb compared to a control intervention. Fifty-three people with severe upper limb deficits between four to 18 weeks post stroke participated in a single blinded randomised controlled trial, in addition to usual care. Participants in the Bobath group (n = 30) were allocated to six one-hour interventions. Those in the control group (n = 26) received a time-matched intervention including passive or assisted active movement, positioning, and sham transcutaneous electrical nerve stimulation. The primary dependent variable was the Pre-Functional Upper Limb Test (PreFULT). Secondary measures included the Stroke Rehabilitation Assessment of Movement (STREAM), grip strength, and the Chedoke Arm and Hand Inventory. Following the intervention, the Bobath intervention group had significantly higher scores on the PreFULT than the control group (p = 0.042); Bobath baseline median 27.2 cm (interquartile range [IQR] 14.9, 73.4), post intervention median 59 cm (IQR 28.7, 136.4; n = 29), control baseline median 21.7 cm (IQR 11.9, 39.6), post intervention median 35.8 cm (IQR 17.4, 63.8, n = 24). Higher scores were observed for the STREAM post intervention for the Bobath group (p < 0.001). No differences between groups were observed for the other measures. Interventions based on the Bobath concept may be more beneficial for recovery of upper limb control in people with severe deficits following stroke than usual care.

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Key Words: Bobath Concept, Rehabilitation, Stroke, Upper limb

INTRODUCTION

Recent research into recovery of the upper limb after stroke has demonstrated that persistent poor recovery is seen in a significant proportion of stroke survivors, particularly when cortico-motor pathways are disrupted (Byblow et al., 2015; Stinear et al., 2012; Stinear et al., 2017). Early recovery of movement in the upper limb is a good prognostic indicator of arm function. For those who have an absence of measurable grip strength or shoulder flexion at four weeks post stroke, there is a strong indication that the upper limb will remain non-functional (Lang et al., 2013). In this scenario, a compensatory approach is often recommended, where the focus is on improving function rather than focusing on improving impairment in the affected limb (Franck et al., 2017; Lang et al., 2013). In contrast, other investigators have sought to improve motor control of the severely affected upper limb using a variety of approaches such as robotic therapy or electromyogram-triggered electrical stimulation (Hayward et al., 2010). Reduction in impairment has been demonstrated in people with moderate to severely affected upper limb function with both robotic therapy and repetitive task practice approaches, without an accompanying improvement in function (Rodgers et al., 2019).

The most commonly utilised outcome measure of upper limb control in people with severe stroke is the upper limb motor subscale of the Fugl Meyer Scale (Franck et al., 2017; Hayward et al., 2010; Kwakkel et al., 2017). This measure is based on the Brunnstrom model of stepwise recovery, where aberrant muscle synergies are observed in early recovery, with more selective control occurring at later stages. However, the goal of treatment in people with severely affected upper limb movement after stroke may be better characterised as the pursuit of directional control of the limb rather than elicitation of aberrant synergies. Having some directional control over the upper limb may make activities of daily living tasks such as dressing easier and enhance use of the limb as a stabiliser in function (Champion et al., 2009), and potentially minimise interference to balance and gait (Carmo et al., 2012; Hirsch et al., 2005).

Demers and Levin (2017) describe arm paresis following stroke as characterised by muscle weakness, changed muscle tone, decreased sensation, and impaired voluntary movement, with the appearance of compensatory patterns, such as excessive trunk displacement and shoulder elevation and abduction commonly observed. Therapy focused on each of these elements and the minimisation of use of compensatory strategies might benefit people with severe stroke. Physiotherapy interventions based on the Bobath concept focus on facilitating selective muscle activation and more normal motor synergies for movement in the context of enhanced postural control and sensorimotor integration (Michielsen et al., 2019).

The aim of this pilot study was to investigate whether a brief series of interventions based on the Bobath concept enhanced directional control of the upper limb in severe stroke, given no previous studies have specifically addressed this question. The primary hypothesis was that a brief intervention of six sessions of rehabilitation therapy based on the Bobath concept would demonstrate greater improvement in directional control of the upper limb in people with severe, persistent upper limb deficits compared to a time matched control condition of additional usual care and sham transcutaneous electrical nerve stimulation (TENS) therapy.

METHODS

This study was a pilot multi-centre single blind (assessor blinded) randomised controlled trial conducted in Melbourne, Australia, between 2008 and 2016. Participants were recruited by consecutive sampling from three rehabilitation centres. Ethical approval was obtained from the St Vincent's Hospital Melbourne Human Research and Ethics Committee (reference HREC A 021/2008) and Western Health Human Research and Ethics Committee (reference HREC A 111/2011). This included approval for gaining consent from next of kin where the individual with stroke did not have capacity to provide informed consent. This trial was retrospectively registered with the Australian New Zealand Clinical Trials Registry (registration number ACTRN12609000970246).

Participants

Participants were eligible for this study if they fulfilled the following inclusion criteria: Were between four and 18 weeks post stroke, infarct or haemorrhage; were able to sit on the edge of the bed with supervision for 5 min; had visually discernible movement (slight movement) of at least one of the following in the affected upper limb: shoulder shrug, elbow flexion, or finger movement; and were able to maintain placement of the affected hand on a table and could follow two-stage commands with gesture.

Participants were excluded if they were able to reach for a cup placed on a table 50 cm in front of the body in sitting (assistance could be provided to place the hand around the cup). Individuals with ataxia, other neurological or musculoskeletal conditions limiting function, irritable shoulder pain, or a cardiac pacemaker (due to use of TENS) were also excluded.

Potential participants were identified by the physiotherapy staff of the inpatient rehabilitation units. Consent to participate was gained by a member of the investigation team. A computer-generated, blocked randomisation procedure was used, with opaque envelopes to conceal group allocation. The randomisation was stratified based on the presence of visually discernible volitional movement of the hand, including movement of thumb or an individual finger, or ability to flex the fingers and let go of flexion to command. Participants were randomised and assigned to groups by an investigator after the baseline measures were carried out.

Sample size calculation was based on preliminary data, where a large effect size for the Pre-Functional Upper Limb Test (PreFULT) was demonstrated (Cohen's d = 0.8) (Luke, 2007). With power set at 0.8 and alpha at 0.05, the study required 26 participants per group to test such effects. Allowing for the dropout rate experienced in the preliminary study (17%), the total number of participants required was 62.

Outcome measures

The primary outcome measure was a measurement tool specifically designed for this study, the PreFULT (Luke, 2007). This outcome measure was developed to assess directional control of the upper limb in people with severe movement deficits, in response to a perceived lack of suitable instruments available in the clinical setting. The PreFULT measures the distance the participant can move a computer mouse on a Union Jack template in eight different directions (see Appendix A for details). The distance the mouse travels down each direction, without crossing the boundaries, is measured and added together for a summed score. The test is completed three times and the average score utilised. Pilot data on the PreFULT has shown high test re-test reliability (intraclass correlation coefficient [ICC] = 0.97) and responsiveness to a brief series of interventions (Luke, 2007).

The secondary outcome measures in this study were used to evaluate active movement control and included the upper limb items of the simplified Stroke Rehabilitation Assessment of Movement (STREAM) (Hsueh et al., 2006), grip strength (Boissey et al., 1999), and bilateral arm function as per the Chedoke Arm and Hand Activity Inventory (CAHAI) (Barreca et al., 2005). The upper limb items of the simplified STREAM evaluate seven isolated movements and three combined movements of the shoulder, elbow, forearm, and wrist and hand on a three-point ordinal scale; 0 for no movement, 1 for part range or full range with deviations, and 2 for full range in a normal pattern (Finch et al., 2009; Hsueh et al., 2006). The upper limb items of the STREAM have high inter-rater reliability (ICC = 0.95) (Wang et al., 2002) and a smallest real difference of 2.8 points (Hsueh et al., 2008). The CAHAI-9 version is a measure of use of the upper limbs across nine functional tasks, where the level of assistance required to achieve the task bilaterally is scored on a scale of 1–7 (Barreca et al., 2006). This measure enables the use of the affected limb in a secondary role as a stabiliser for some tasks, potentially having less of a floor effect than other functional measures of upper limb recovery. Grip strength was measured with a dynamometer with the arm supported on a table and the shoulder in neutral and the elbow at 90^0 flexion, with assistance provided to maintain neutral forearm rotation and prevent wrist flexion.

Measures were obtained by an assessor (SB) blinded to group allocation. Assessments were conducted between one to five days prior to commencement of the intervention and between one to five days following completion of the six intervention sessions. The order of testing was standardised, with the PreFULT tests conducted first, followed by the STREAM, grip strength, and the CAHAI.

Interventions

All participants received six one-hour sessions over a period of two weeks, additional to their usual care. Usual care in the participating rehabilitation units included physiotherapy and occupational therapy sessions provided either daily or several times a week. These sessions may have included therapy directed towards the upper limb; however, therapy sessions may have had a greater focus on activities enabling discharge home such as mobility in physiotherapy and independence in daily living activities in occupational therapy.

Participants allocated to the experimental group received interventions based on the Bobath concept. Bobath-based interventions were individually prescribed (Michielsen et al., 2019) in response to assessment findings with regard to postural abilities, motor control of the upper limb, sensory impairments, and the presence or absence of disorders such as neglect and dyspraxia. The treatments provided included promoting postural control for selective movement, facilitation of specific muscle activation and inter-joint co-ordination, facilitation of more normal movement patterns during task performance, and upper limb activities, both novel and daily life activities, in many postures (Champion, 2009). To further characterise interventions based on the Bobath concept, two case studies with participants with differing underlying impairments (poor postural control and dyspraxia) are available online at www.bobathaustralia.org/publications/ULcasestudies.

Participants allocated to the control condition received a time-matched upper limb intervention representing additional usual care plus a sham intervention. Active assisted or passive movements of the arm were performed in supine with 10 attempts at the following movements: shoulder flexion (maximum 90°)/extension, elbow flexion/extension, forearm pronation/supination, wrist flexion/extension, and finger flexion/extension across the full range of movement unless limited by pain. The participant was encouraged to attempt the movements, which were performed slowly. If the participant was unable to contribute, the movement was completed passively. Shoulder prolonged positioning was conducted in supported sitting with the shoulder placed in 90° abduction and external rotation, with the elbow extended for 10 min. If this position was painful, the shoulder was positioned and supported as close to this position as could be achieved without pain. This usual care intervention shares elements with the Concise Arm and Hand Rehabilitation Approach in Stroke (CARAS) protocol for upper limb recovery, where the focus of therapy for those with minimal movement was "taking care and prevention", including positioning, maintaining joint and muscle mobility, strategies for minimising discomfort, and exercises provoking voluntary movement where possible (Franck et al., 2017).

Sham TENS was applied for 20 min in supine, with the arm beside the body. Prior to commencing, the function of the TENS unit was demonstrated by applying the TENS to the less affected side and determining the dose where the participant could feel the tingling sensation. Participants were told that a dose slightly lower than this would be applied to the affected side and that they may or may not feel it. The TENS unit was attached in the same way to the affected shoulder with the control unit out of sight and not switched on. In the ethical review process, permission was granted for this degree of deception to encourage participants to view the two interventions as equivalent to control for the placebo effect.

It should be noted that the original study design registered with ANZCTR involved a sham intervention only rather than usual care plus a sham component. The sham intervention only involved passive movement of the upper limb. However, this was immediately identified as unsustainable. Participants were eager to attempt active movement during the therapist's movement of the upper limb and preventing this would remove all attempts at blinding the participant to the intervention being investigated. Therefore, the design of the control group was modified to usual care plus sham TENS.

Both interventions were performed by physiotherapists with at least 5 years' postgraduate experience and 2 years' experience in the fields of rehabilitation or neurology. In addition, therapists providing the Bobath intervention had to have completed a minimum of two advanced Bobath courses. All interventions were provided on a one-to-one basis. Seven physiotherapists were involved in delivering both interventions.

Data analysis

Data from interval scored outcome measures (PreFULT and grip strength) were screened for normality to determine the appropriate statistical tests. If data met assumptions of normality, the planned statistical analyses detailed in the clinical trial registry included assessing between group differences for parametric variables using one-way analyses of variances (ANOVA). However, the data did not meet assumptions of normality, (PreFULT skewness 1.5, standard error [SE] 0.33, kurtosis 1.65, SE 0.64; grip strength skewness 4.0, SE 0.33, kurtosis 18.37, SE 0.65). Therefore, all data were analysed with non-parametric statistics, including the Wilcoxin signed ranks test for within group analysis and the Mann Whitney U for between group analysis.

RESULTS

Fifty-six participants were recruited to the trial with 53 completing both the baseline and follow-up testing sessions (Figure 1). Demographics and medical data for participants who completed the study are shown in Table 1, with baseline and post intervention data for each outcome variable presented in Table 2.

Figure 1

Participant Flow Diagram

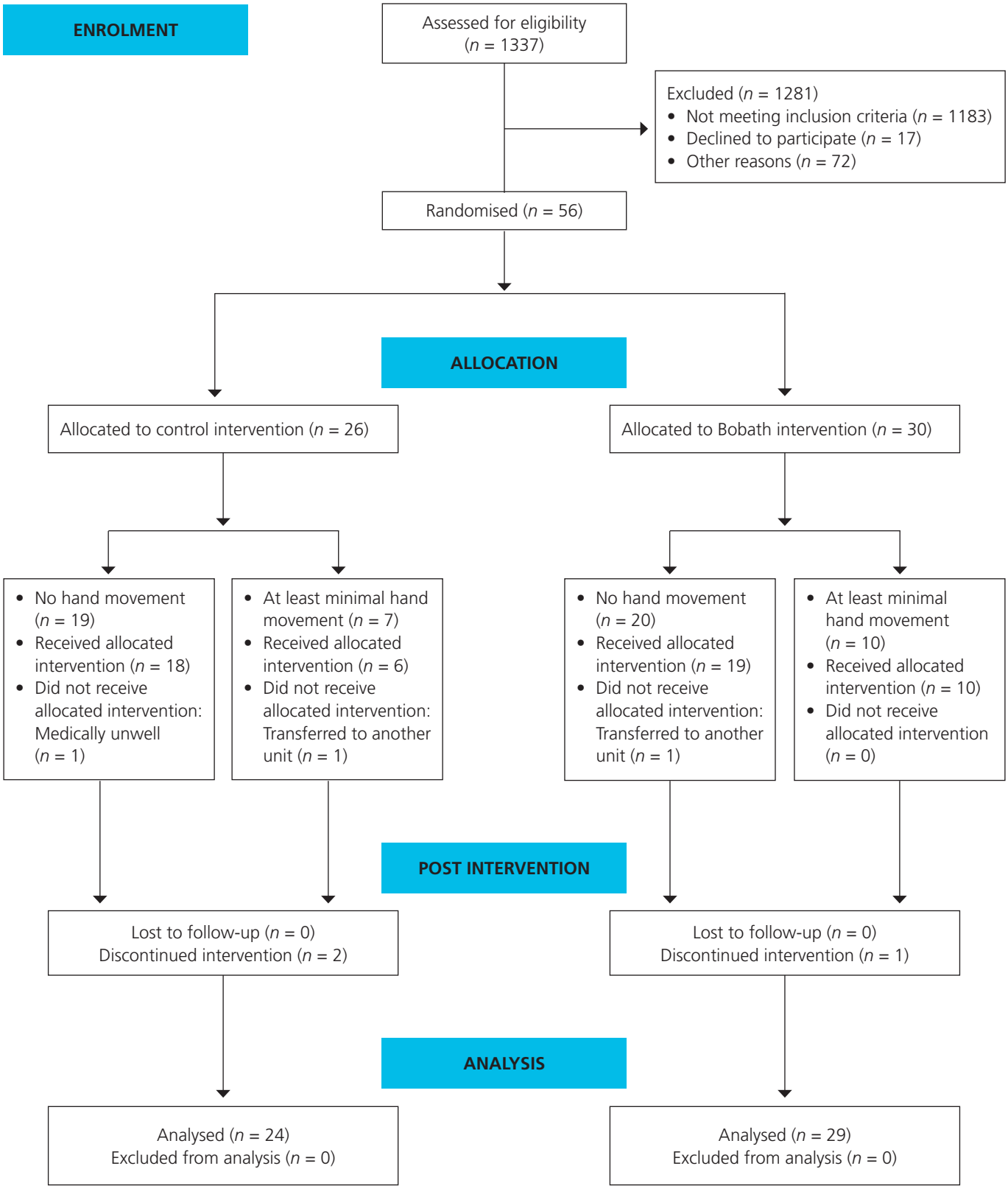


Table 1

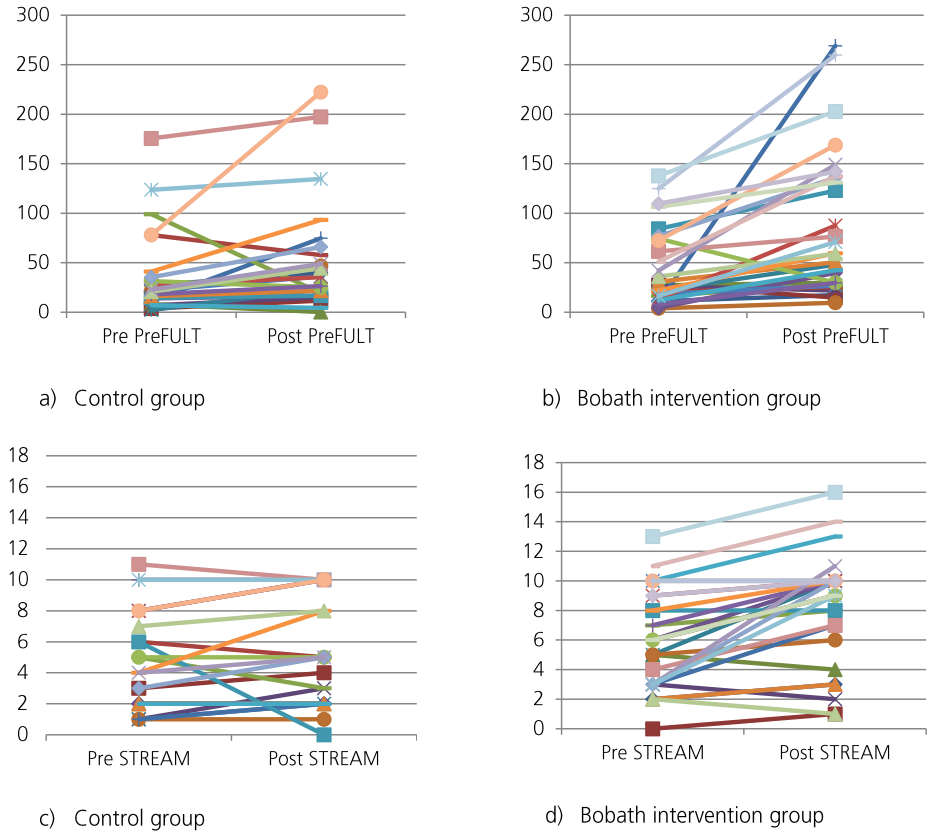
Demographic and Medical Variables

Characteristic	Control group (n = 24)		Bobath group (n = 29)		p
	n	%	n	%	
Age (years), mean (SD)	57.4 (15.7)		60.8 (15.2)		0.44
Gender					
Male	15	62.5	15	51.7	
Female	9	37.5	14	48.3	
Time since stroke (days), mean (SD)	57.4 (21.2)		67.5 (28.4)		0.24
Side of hemiparesis, right	14	58.3	15	48.3	
Pathology, infarct	15	62.5	18	62.1	

At baseline, no significant differences were observed between groups for all measures. Within group analysis showed improvement in scores for both groups for all variables except the control condition for the STREAM assessment (p = 0.22) (Table 2). Post intervention, significant differences between the two groups were observed for two of the variables, the PreFULT and the STREAM, in favour of the Bobath intervention (Figure 2). No significant differences were observed for grip strength or the CAHAI. The comparison between groups for the main dependent variable, the PreFULT, was conducted using intention to treat principles, with the baseline score carried forward for the three non-completing patients. This yielded similar results with a significant difference favouring the Bobath group (Bobath median 59 [IQR 28.7, 136.5]; control median 35.9 [IQR 18.6, 59.76], p = 0.045).

Figure 2

Baseline and Post-intervention Scores for Individual Participants



Note. Each individual is represented by a different coloured line. PreFULT = Pre-functional upper limb test; STREAM = Stroke Rehabilitation Assessment of Movement.

Table 2

Baseline and Post-intervention Measures for Outcome Variables

Measure Group	Baseline		Post-intervention		Within group significance	Between group significance	
	Mdn	IQR	*Mdn*	IQR		Baseline	Post-intervention
PreFULT (cm)							
Bobath	27.2	14.9, 73.4	59.0	28.7, 136.4	< 0.001*	0.372	0.042
Control	21.7	11.9, 39.6	35.8	17.4, 63.8	0.005*		
STREAM							
Bobath	6	3, 9	9	6.5, 10	< 0.001*	0.096	< 0.001*
Control	4	2, 8	4.5	2, 8.8	0.223		
Grip strength (kg)							
Bobath [a]	0	0, 0.16	0.05	0, .37	0.013*	0.991	0.838
Control	0	0, 0.22	0.05	0, .59	0.003*		
CAHAI							
Bobath [a]	10.0	9.0, 12.8	10.5	9.0, 14.8	0.001*	0.819	1.00
Control [b]	9.5	9.0, 12.3	11.0	9.0, 12.8	0.017*		

Note. Number of participants in Bobath group = 29 and control group = 24, except where indicated. CAHAI = Chedoke Arm and Hand Inventory 9 (scored out of a total of 63, higher is better); IQR = interquartile range; PreFULT = Pre-Functional Upper Limb Test (scored out of a total of 300; higher is better); STREAM = Stroke Rehabilitation Assessment of Movement upper limb subscale (scored out of a total of 20; higher is better).

[a] $n = 28$. [b] $n = 22$. * $p < 0.05$.

DISCUSSION

This study investigated whether people with minimal recovery of the upper limb between four and 16 weeks after stroke can demonstrate improvement in motor control of the limb following interventions based on the Bobath concept. The results indicate that a brief series of interventions based on the Bobath concept may be more effective in improving the ability to perform directional movements of reaching on a table top with some precision, as measured by the PreFULT, compared to interventions based on additional usual care. Similar improvements in motor control were observed for the STREAM.

The approach to upper limb recovery after stroke has been the subject of debate in recent times. The negative results from large trials investigating the effectiveness of task-oriented therapy with intensive practice (Lang et al., 2016; Winstein et al., 2016) have caused some authors to reconsider future directions for rehabilitation of the upper limb. Demers and Levin (2017) recommend a greater focus on quality of movement (temporal and spatial joint co-ordination and muscle activation patterns) as well as movement outcomes. Similarly, Krakauer and Cortés (2018) argue that a non-task oriented approach may be more beneficial for recovery from motor impairment, minimising compensatory strategies, and facilitating directional control. The Bobath concept has a strong focus on quality of movement, where manual facilitation by the therapist is a tool utilised to improve muscle activation for the initiation of movement and inter-joint co-ordination during movement (Levin & Panturin, 2011). Interventions involve a wide repertoire of upper limb activities in many different postures to regain selective control of the upper limb even where damage to the cortex from stroke is too great to enable functional hand use (Champion et al., 2009). It should be noted that the benefits observed for directional control of the upper limb in this study resulted from a brief intervention of six one-hour sessions. Use of the Bobath concept is resource intensive, requiring one-to-one interaction with a skilled therapist. However, this may be as cost effective as other therapies if relatively small doses of therapy can improve motor control.

Both the Bobath intervention group and the control group improved in their movement control abilities with a small amount of therapeutic input. This was an unexpected finding. We deliberately selected participants who were beyond a four-week window of early recovery to focus on persistent, severe upper limb deficits. In contrast, in our preliminary study, participants showed no improvement over a two-week period, then significant improvement with additional interventions based on the Bobath concept. Those in the control group may have benefitted from the systematically applied assisted active movements as well as the additional focus on the upper limb.

In considering the outcomes of this study, it must be acknowledged that there has been limited investigation of reliability and validity of the primary dependent variable, the PreFULT. This measure was chosen for the study as a simple clinical test that can yield data about precision of movement control in people with severe upper limb deficits post stroke. We chose to use this test rather than commonly used tools for severe upper limb deficits, such as the Fugl Meyer upper limb motor subscale, because we were interested in whether the person with stroke could improve in precision of movement rather than simply produce movements in a relatively

unspecified way. The PreFULT can be used to investigate trajectories of movement in the clinical setting. The test requires the patient to maintain hand posture on the mouse while moving the arm, limiting use of abnormal synergies, while the use of a back brace limits compensatory trunk movement (Michaelsen et al., 2006). It is notable that all participants were able to score above zero in this test, showing minimal floor effects, whereas, in contrast, the median score for grip strength at baseline was zero. In this study, the PreFULT was shown to be responsive to change following a brief intervention. Unlike most measures suitable for severe upper limb deficits, the PreFULT is less dependent on subjective ratings of quality or range of movement. The test yields objective data that initial investigations indicate might have excellent reliability (Luke, 2007).

For the STREAM assessment, the Bobath intervention group achieved significantly higher scores following the intervention beyond the smallest real difference of 2.8 points, whereas the control group did not achieve significant change. However, there was a trend for higher scores at baseline in the Bobath intervention group. Small improvements were noted for both groups for the secondary variables of grip strength and the CAHAI; however, no differences between groups were observed. This was not surprising as we did not anticipate functional changes from such a brief series of interventions. Rather we were interested in whether people with stroke could develop some directional control of the upper limb; that it is neither hanging dependent and unresponsive to the body, or stiff and immobile, interfering with mobility.

Other limitations to this study pertain to the relatively small sample size. There was a tendency for the Bobath group to have higher sores at baseline for most of the variables, although this did not reach significance. It should be noted that the study was single blinded, with blinding of the assessors only. Due to the requirements of informed consent, participants were aware of the intervention they were randomised to; however, as described previously, the consent form presented the two interventions as equivalent. The therapists also were aware of the intervention being delivered. For these reasons, the conclusions from the study must be tentative and require reproduction in another sample. Also, no follow-up evaluations were undertaken to determine whether the improvements were maintained over time. Future research should consider whether these changes are maintained and whether having some directional control of the limb has benefits for people with severe stroke who are unlikely to have return of selective hand function.

This pilot study has demonstrated that investigating Bobath-based interventions for people with severe deficits of the upper limb post stroke in the subacute inpatient phase is feasible. Increasing the number of centres recruiting participants or including centres with larger cohorts of people with stroke would reduce the time taken to achieve recruitment targets in future studies. Inclusion of participants who required next-of-kin consent because of cognitive or communication deficits was vital in this study in order to achieve a representative sample of people with severe stroke and to meet recruitment targets.

CONCLUSION

The results of this study indicate that directional control of the upper limb can improve with a brief intervention even with severe, persistent upper limb deficits following stroke. Interventions based on the Bobath concept may be more beneficial than additional usual care. The PreFULT appears to be a promising approach to measurement in the clinical scenario.

KEY POINTS

1. Directional control of the upper limb in people with severe stroke can improve with a brief intervention.
2. Interventions based on the Bobath concept may be beneficial for recovery of directional control of the upper limb.
3. The PreFULT may be a useful clinical measure for demonstrating improvement in upper limb control in severe stroke.

DISCLOSURES

Three organisations provided funding support for this project: the Stroke Foundation, St Vincent's Hospital Melbourne Research Endowment Fund, and the International Bobath Instructor Training Association.

Kim Brock and Melissa Birnbaum are members of the International Bobath Instructor Training Association.

PERMISSIONS

This study was approved by the St Vincent's Hospital Melbourne Human Research and Ethics Committee (reference: HREC A 021/08). Informed consent was obtained from participants or from their next of kin.

Photographs in the case studies (available online) were taken with informed consent as a sub-study of the main study. Additionally, facial features have been obscured to protect anonymity.

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CONTRIBUTIONS OF AUTHORS

KB and CL initiated the study and developed the study design. JT, JS and SB were provider physiotherapists and contributed to the interpretation of results and revision of the manuscript. KB was responsible for data processing and analysis and writing of the first manuscript draft. All authors approved the final draft.

CORRESPONDING AUTHOR

Kim Brock, Physiotherapy Department, St Vincent's Hospital, Melbourne, PO Box 2900, Fitzroy, Victoria, Australia 3065.

Email: kim.brock@svha.org.au

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Appendix A

TESTING EQUIPMENT AND PROCEDURES FOR THE PREFULT

Testing equipment

- A template of paper 110 x 60 cm with 8 x 2 cm wide lines drawn in a Union Jack formation including a vertical line, horizontal line and two lines intersecting at 45°.
- Drafting tracing paper sufficient to cover the template.
- Clips to hold the template and tracing paper in place on a table.
- A computer mouse with the ink tube of a pen inserted through a drilled hole.
- A rigid spinal brace (Knight Taylor Brace, Kydex).

Procedures

- The participant sits at a seat without armrests and the spinal brace is strapped to the chair with Velcro straps at 90° angles in front of a table. The participant's rib cage is perpendicular to the support (Figure 3).
- The participant's xiphisternum is in line with the centre marker.
- The height of the table is adjusted to the level of the participant's olecranon.
- The shoulder straps are adjusted to allow the width of three fingers to fit under the strap. This is to allow some movement of the upper trunk and scapula but to restrict movement of the hips and lower trunk away from the backrest.
- The table is moved as close to 10 cm from the xiphisternum as possible.
- The template on the table is positioned so the centre point is 60% of the length of the participant's forearm away from the edge (i.e., centre point is 10 cm + 60% of length of forearm away from xiphisternum).
- The non-hemiplegic hand is placed palm down on the table, elbow supported and shoulder in neutral.
- The participant's hand is placed on the computer mouse with the distal interphalangeal joint of the index finger next to the pen, the middle finger distal interphalangeal joint on the other side of the pen, and the thumb on the side of the mouse. The assessor moves the hand and mouse to the centre marker so the top of the mouse is on the intersecting lines of Line 1.
- The participant's olecranon must be resting on the table. If this is not possible, due to body shape constraints, then the table may be moved closer to the xiphisternum until the elbow can rest on the table and the new distance recorded.
- If the mouse does not remain on the centre marker when the assessor removes their assistance, the assessor places the participant's palm down on the table flat for 15 s and reattempts to place the hand on the mouse again. If the hand does not remain on the centre marker after three attempts, testing must be discontinued.
- The participant is instructed to "move the pen between the lines as far as you can. Let me know when you cannot go any further and I will move your hand back". When the participant can no longer move the mouse further along the line, the assessor lifts the hand back to the centre marker for the next trial.
- The participant performs three trials on each line in each direction. The participant starts with the line at 45° from the horizontal, opposite to the hemiplegic side, followed by the line moving directly vertical away from their body and then continuing around the lines in the same clockwise or anticlockwise direction. The assessor marks each line as the first, second, or third attempt.
- On completing the task, the assessor measures the score. The furthest distance the pen reaches between the 2 cm-wide line or the furthest point where the pen leaves the 2 cm-wide line and is unable to return is measured as shown in Figure 2. If the pen trace did not leave the centre square surrounding the centre marker, the trial is recorded as 0 as shown in Figure 4. All three trials of each line are recorded.

Figure 3

Set Up of the PreFULT Task

Figure 4

Measurement of PreFULT Task