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The Effectiveness of the Bobath Concept in Stroke Rehabilitation

What is the Evidence?

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Background and Purpose—In the Western world, the Bobath Concept or neurodevelopmental treatment is the most popular treatment approach used in stroke rehabilitation, yet the superiority of the Bobath Concept as the optimal type of treatment has not been established. This systematic review of randomized, controlled trials aimed to evaluate the available evidence for the effectiveness of the Bobath Concept in stroke rehabilitation.

Method—A systematic literature search was conducted in the bibliographic databases MEDLINE and CENTRAL (March 2008) and by screening the references of selected publications (including reviews). Studies in which the effects of the Bobath Concept were investigated were classified into the following domains: sensorimotor control of upper and lower limb; sitting and standing, balance control, and dexterity; mobility; activities of daily living; health-related quality of life; and cost-effectiveness. Due to methodological heterogeneity within the selected studies, statistical pooling was not considered. Two independent researchers rated all retrieved literature according to the Physiotherapy Evidence Database (PEDro) scale from which a best evidence synthesis was derived to determine the strength of the evidence for both effectiveness of the Bobath Concept and for its superiority over other approaches.

Results—The search strategy initially identified 2263 studies. After selection based on predetermined criteria, finally, 16 studies involving 813 patients with stroke were included for further analysis. There was no evidence of superiority of Bobath on sensorimotor control of upper and lower limb, dexterity, mobility, activities of daily living, health-related quality of life, and cost-effectiveness. Only limited evidence was found for balance control in favor of Bobath. Because of the limited evidence available, no best evidence synthesis was applied for the health-related quality-of-life domain and cost-effectiveness.

Conclusions—This systematic review confirms that overall the Bobath Concept is not superior to other approaches. Based on best evidence synthesis, no evidence is available for the superiority of any approach. This review has highlighted many methodological shortcomings in the studies reviewed; further high-quality trials need to be published. Evidence-based guidelines rather than therapist preference should serve as a framework from which therapists should derive the most effective treatment. (*Stroke*. 2009;40:e89-e97.)

Key Words: Bobath ■ cerebrovascular disorders ■ neurodevelopmental treatment ■ physical therapy ■ rehabilitation ■ systematic review

Before the introduction of neurophysiological approaches to rehabilitation, patients with central nervous system damage were re-educated using both a compensatory and an orthopedic approach consisting of stretching, bracing, and strengthening the affected side and teaching the patient to rely more heavily on the unaffected side to become as independent as possible.¹ Concomitant with advances in motor

control and neurosciences of the last decades went the development of new innovative interventions for neurologically impaired patients. One of these approaches is the Bobath Concept, which was last published by Bertha and Karl Bobath in 1990.² Bobath explained movement dysfunction in hemiplegia from a neurophysiological perspective stating that the patient must be active while the therapist assists the

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patient to move using key points of control and reflex-inhibiting patterns.² Since 1984, the Bobaths conceded that reflexes were not primitive responses, but essential reactions to support movement; as a consequence, the missing components of the normal developmental sequence were no longer facilitated during Bobath therapy in either adults or children.³ It is thus unfortunate that the Bobath Concept is still referred to as NeuroDevelopmental Treatment (NDT) in the American literature because it was originally based on facilitating the missing components of the normal developmental sequence in children with cerebral palsy. More than 50 years later, this treatment approach that is based on their revolutionary ideas has become the most popular approach for the treatment of neurologically impaired patients in the Western world.⁴

In the past 2 decades, a better understanding has developed of the underlying mechanisms that are responsible for motor learning⁵ and functional recovery after stroke.⁶ Recent studies suggest that different mechanisms are involved in generating the nonlinear pattern of neurological recovery after stroke. These mechanisms include: (1) salvation of penumbral tissue surrounding the infarcted area; (2) elevation of cerebral shock (ie, "elevation of diaschisis"); and (3) the ability of the brain to adapt by neuroplasticity. These mechanisms are not independent from each other, but are likely highly interrelated. For example, neurons that are anatomically related to the infarcted area, that is in the process of recovering from a suppressive state, can restore their function by inducing plastic changes such as receptor hypersensitivity and dendritic growth of new interneuronal pathways. Recent studies also suggest that mechanisms of experience-dependent plasticity are further enhanced by exercise training.⁷ This relationship is subject to a dose–response increase, ie, more intense training leads to a better response.⁸ However, there is also a growing body of evidence that functional recovery entails more than just the restitution of body functions. In particular, recent longitudinal studies that examined human kinematics showed that improvement in dexterity and gait is to a large extent based on the use of compensatory movement strategies by which patients learn to deal with existing deficits.⁶

As a result of this gradual accumulation of scientific knowledge, the Bobath Concept has evolved into its current form by selectively incorporating this knowledge.^{9–12} The International Bobath Instructors Training Association (IBITA) defines the current Bobath Concept as a problem-solving approach to the assessment and treatment of individuals with disturbances of function, movement, and postural control due to a lesion of the central nervous system; the association clearly states that the Bobath Concept aims to identify and analyze problems within functional activities and participation in everyday life as well as the analysis of movement components and underlying impairments.¹² The British Bobath Tutors' Association (BBTA) supports this view that although the Bobath Concept targets both impairments and functional activities, successful goal acquisition in a given task must be practiced to improve efficiency of movement and promote generalization in everyday life.¹¹ These main adaptations to current Bobath practice concur with the evidence base for applying exercise therapy at a

functional level and preferably in the patient's own environment, because the effects of impairment-focused training rarely generalize to activities that are not directly trained in the treatment program and also that these generated effects are context-dependent.^{13–15}

In the past decade, the theoretical assumptions underlying the Bobath Concept have been subject to criticism^{1,4,16}; despite its popularity, the Bobath Concept has never been proven to be superior to alternative treatment approaches.¹⁷ Although 2 systematic reviews have specifically examined the effectiveness of Bobath-based therapy reviewing papers up to 2001¹⁸ and 2003,¹⁶ in light of the growing number of randomized, controlled trials, the improved understanding of mechanisms underlying adaptive motor relearning and mechanisms of functional recovery after stroke and the different policies to deal with the lack of evidence for the efficacy of Bobath therapy, we have systematically evaluated the evidence for the effectiveness of the Bobath Concept in stroke rehabilitation when compared with alternative approaches in terms of outcome of: (1) sensorimotor control of the upper and lower paretic limb; (2) balance control; (3) dexterity; (4) mobility; (5) activities of daily living (ADLs); (6) health-related quality of life (HRQOL); and (7) cost-effectiveness.

Methods

Identification and Selection Criteria

Publications were retrieved from the bibliographic databases CENTRAL (searched in the Cochrane Library, March 2008) and MEDLINE (searched in PubMed, March 2008). In PubMed, only MeSH terminology was applied combined with the sensitive Cochrane filter for reviews on interventions and limited to humans. In CENTRAL, only free-text terms were applied. The detailed search profiles and proceeds are available on request from the corresponding author. The references of retrieved trials and other relevant publications, including reviews and meta-analyses, were examined.

The following criteria were used for including studies: (1) only involvement of adult patients with a cerebrovascular accident; (2) effects of the Bobath Concept were compared with those of an alternative method; (3) randomized, controlled clinical trial (RCT); (4) rehabilitation outcomes were measured in one or more of the following domains: sensorimotor function of the upper and/or lower extremity, balance control, mobility, dexterity, ADL, HRQOL, and cost-effectiveness; and (5) only English or Dutch publications were considered for inclusion; letters, dissertations, abstracts and case reports were excluded.

The Bobath Concept is also known as neurodevelopmental treatment; for the present study, Bobath and neurodevelopmental treatment were seen as synonyms for the same approach. Other synonyms (eg, conventional therapy) were accepted only when the therapy was based on the Bobath Concept (or neurodevelopmental treatment). In the present review, stroke was defined according to the World Health Organization definition as: a clinical syndrome typified by rapidly developing signs of focal or global disturbance of cerebral functions, lasting more than 24 hours or leading to death, with no apparent causes other than vascular origin.¹⁹

The International Classification of Functioning and Disability²⁰ examines outcomes in terms of 3 health domains; impairments, activity restrictions, and participation restrictions with consideration of environmental and personal contextual factors. In this review, impairments of sensorimotor control of the upper and lower extremity (eg, shoulder pain, muscle tone, range of movement, muscle strength, and motor control [the initiation and coordination of muscle control during a movement]) and balance control (eg, the ability to maintain a stable sitting or standing posture over a period of time)

were included. In the activity restriction domain, dexterity included the ability to perform tasks such as reaching, grasping objects, and fine hand use; mobility was defined as the ability to (re)position the body by transfer or gait; and ADLs were defined as the ability to perform basic activities of self-care. Outcomes related to social, emotional, and cognitive functioning were defined as HRQOL and have been included in the participation restriction domain. The influence of environmental and personal contextual factors was not examined.

Assessment of Validity of the Study

Decision for inclusion in the present review was made by 2 assessors (K.S., M.C.S.). The 2 assessors independently evaluated the identified publications, classified the identified studies according to predetermined criteria, and reviewed the methodological quality of each study using the Physiotherapy Evidence Database (PEDro) methodological scale.²¹ The PEDro scale was developed for rating quality of RCTs and contains 11 items. The first item represents external validity of the trial. This item is not included in the total PEDro score (maximum 10); therefore, our score is based on Items 2 to 11. These items represent 2 aspects of trial quality, the internal validity of the trial and whether the trial contains sufficient statistical information. These items are scored either yes (1 point) or no or not applicable (0 points). The individual item scores and the total PEDro scores have been shown to be reliable.²² Studies with PEDro scores of ≥ 4 points were classified as "high quality," whereas scores of ≤ 3 points were classified as "low quality."²³ During a consensus meeting, scoring disagreements were resolved. In the event agreement could not be reached, a third reviewer (G.K.) decided on the final score. Reviewers were not blind to author(s), institution(s), or journals.

Best Evidence Synthesis

Pooling of the studies was not feasible because of methodological heterogeneity in interventions, patient characteristics, and outcomes. To address the evidence for Bobath-based intervention, a best evidence synthesis (BES) was applied based on the criteria of Tulder et al.²⁴ These criteria are based on the PEDro scale. Selected studies were categorized into 5 levels of evidence: (1) strong evidence; (2) moderate evidence; (3) limited evidence; (4) indicative findings; and (5) no or insufficient evidence (see supplemental Table I, <http://stroke.ahajournals.org/>). This categorization reported more recently in Van Peppen et al²⁵ further stipulates that if the number of studies with a comparable outcome measure that shows evidence is $< 50\%$ of the total number of studies found within the same category of methodological quality and study design (eg, RCTs in this review), no evidence will be classified.

Results

The search strategy initially identified 2263 studies (Cochrane Library: 1146, PubMed: 1223, overlap: 106). After selection on title, abstract, and language, 39 studies satisfied the criteria and were further scrutinized. From these remaining studies, 8 were excluded because they did not evaluate the effectiveness of Bobath as an intervention in an experimental and a control group.^{4,25–31} Four studies were written in a language other than English or Dutch with no available translations.^{32–35} One study used Bobath as a treatment modality for patients with Parkinson disease and was therefore excluded.³⁶ A paper by Moseley et al³⁷ was excluded because it was a critique of another study, which is included in this review,³⁸ and one study was excluded because it was uncertain whether Bobath was the control intervention.⁸ Finally, 6 studies were excluded due to study design. Thus, based on this selection, 21 studies were excluded and 18 studies proceeded for further analysis (Figure). This number was reduced to 16 because Langhammer and Stanghelle^{39,40}

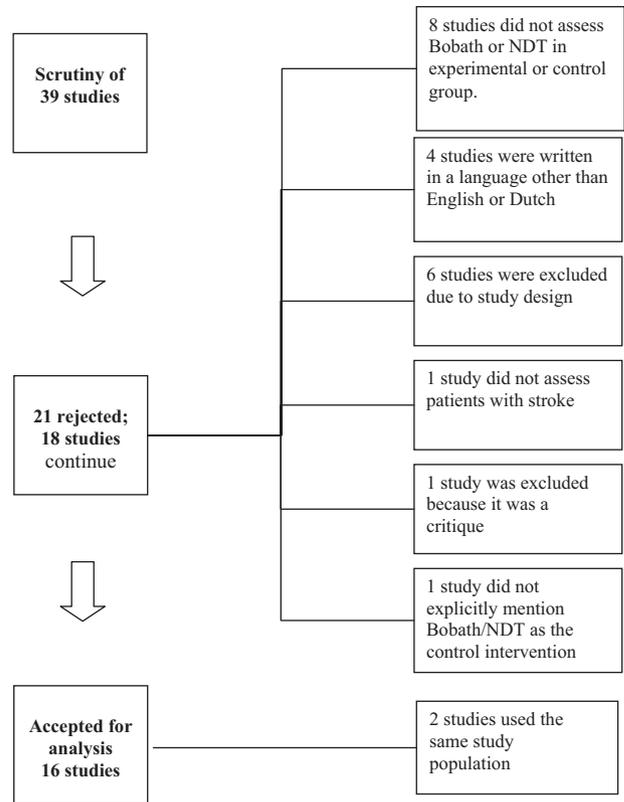


Figure. Flow chart of studies selected.

and Platz et al^{41,42} refer to the same data; therefore, these 4 papers have been considered as 2 studies.

Methodological Quality

The results of the PEDro scores of 16 trials involving 813 patients are presented in supplemental Table II (<http://stroke.ahajournals.org/>). Initially, there was disagreement on 13 of the 160 criteria scored. Based on Cohen's kappa, an interrater-reliability of 0.79 was calculated. The PEDro scores varied from 4 to 8 out of the maximum possible score of 10 without including the first item of the PEDro scale. It is worth noting that it is difficult to blind therapists delivering the intervention or participants in rehabilitation-type trials; therefore, the maximal achievable score for a high-quality study is likely to be 8 out of 10. All RCTs used a random allocation procedure and 8 trials concealed the allocation of treatment.^{38,41,43,45–49} Only one study did not provide information about concealment of allocation.⁵⁰ At baseline, no difference between the experimental and control subjects was reported in 11 trials.^{38,39,41,43,44,45,49,50,51–53} Seven studies used blinding of all subjects.^{38,39,43,44,48,51,52} Eleven studies used independent assessors for outcomes^{38,39,41,43–46,48–51} In 11 studies, 85% of the subjects were measured for at least one key outcome,^{38,39,41–45,48,49,53,54} whereas in 10 studies, an intention-to-treat analysis was performed.^{38,39,41,43–46,48,49,53} The results of between-group statistical comparison were reported in all studies. Likewise, all studies reported point estimates and variability information.

Sensorimotor Control of the Upper Extremity

Seven of 16 studies investigated the effect of the Bobath Concept on regaining sensorimotor control of the upper parietic

limb after stroke (supplemental Table III)^{39,40–44,48,51,53} (see <http://stroke.ahajournals.org/>).

Best Evidence Synthesis

Seven studies were included in the BES for sensorimotor control of the upper extremity. All articles scored ≥ 6 points and all were classified as high-quality RCTs. The median PEDro score was 7 (range, 6 to 8).

Three studies (3 of 7) demonstrated a significant between group improvement in favor of other approaches^{41,42,44,51}; the remaining 4 papers showed no significant differences between approaches.

Therefore, no BES could be classified for the superiority of Bobath therapy or any other approach on sensorimotor control of the upper limb.

Sensorimotor Control of the Lower Extremity

Four of the 16 studies investigated the effects of Bobath on restoring sensorimotor control of the lower extremity after stroke (supplemental Table III)^{39,40,43,45,53,43} (see <http://stroke.ahajournals.org/>).

Best Evidence Synthesis

The BES for sensorimotor control of the lower extremity was based on 4 studies. All studies scored ≥ 6 points and were classified as high-quality RCTs. The median PEDro score was 7 (range, 6 to 8).

Only 2 of 4 studies^{39,45} demonstrated a significant between-group improvement for these items. Changes in tone were observed in the study by Wang et al⁴⁵ showing positive findings in favor of the Bobath Concept, whereas Motor Relearning Programme showed superiority over Bobath Concept in lower extremity motor control.³⁹ No BES could be classified for the superiority of Bobath therapy or any other approach.

Balance Control

Four studies (4 of 16) investigated the effects of Bobath therapy on symmetry of weight distribution over hemiplegic and non-hemiplegic sides and balance control assessed with the Motor Assessment Scale or the Berg Balance Scale (supplemental Table III)^{43,45–47} (see <http://stroke.ahajournals.org/>).

Best Evidence Synthesis

Four studies were included in the BES for balance control in terms of symmetry of weight distribution over hemiplegic and nonhemiplegic sides^{46,47} and outcome of Motor Assessment Scale⁴³ or Berg Balance Scale.⁴⁵ All 4 studies scored ≥ 4 points on the PEDro scale and therefore were classified as high-quality RCTs. The PEDro score ranged from 4 to 8 (median 7). Two studies focused on symmetry in weight distribution over the paretic and nonhemiplegic sides and the other 2 measured balance control either by Motor Assessment Scale⁴³ or Berg Balance Scale.⁴⁵ One of each (symmetry and balance control) showed positive findings in favor of the Bobath Concept, although the study on symmetry also reported long-term benefits for Body Performance Monitor training. Based on van Tulder's BES, we suggest that there is limited evidence for the superiority of Bobath Concept.

Dexterity

Six of 16 studies investigated the effects of the Bobath Concept on dexterity in patients with stroke (supplemental Table III)^{41,43,48,50,52,54} (see <http://stroke.ahajournals.org/>).

Best Evidence Synthesis

Six studies were included in the BES that investigated the effects of Bobath therapy on dexterity in patients with stroke. All studies reached a score of ≥ 4 on the PEDro scale with a median score of 6 (range, 4 to 8).

There was no evidence of effect of Bobath on dexterity in any of the 6 studies included. Of these studies, one⁴⁸ demonstrated superiority of Forced Used Therapy for a subgroup of patients with hemineglect, and another⁵⁰ showed superior effects for the entire Constraint Induced Movement Therapy group. As a consequence, no BES could be classified for the superiority of Bobath therapy or any other approach at restoring dexterity.

Mobility

Seven of 16 studies reported the effects of Bobath therapy on mobility after stroke (supplemental Table III)^{38,43,45,48,53–55} (see <http://stroke.ahajournals.org/>).

Best Evidence Synthesis

All studies scored ≥ 4 points and all were classified as high-quality RCTs. The median PEDro score was 7 (range, 4 to 8).

The individual data regarding the change from baseline for each group was not reported in 2 studies^{54,55}; therefore, the effect for each intervention separately could not be examined in these studies. Within the remaining 5 studies, one study reported significant effects for improving walking ability within the Bobath group⁴⁵; 3 studies reported significant effects for other interventions,^{38,49,53,54} and van Vliet et al⁴³ reported no difference within either group separately. Only Eich et al³⁸ examined gait parameters such as gait velocity within groups reporting significant improvements within the treadmill training group but not within the Bobath group.

Four studies (4 of 7) demonstrated between significant group effects on walking ability in favor of Problem Oriented Willed Movement, Rhythmic Auditory Stimulation, and treadmill training.^{38,49,53,55} Wang et al⁴⁵ reported significant effects in favor of the Bobath Concept, whereas the remaining 2 studies showed no superiority between approaches. With regard to walking velocity examined in 4 of 7 studies,^{38,49,54,55} 2 studies reported significant effects in favor of other approaches, whereas Gelber⁵⁴ found a significant between-group effect in favor of the Bobath Concept.

No BES could be classified for the superiority of the Bobath Concept on mobility. Based on van Tulder's BES rule, there was strong evidence in favor of other approaches; however, because the other intervention was quite different in each study except for Thaut et al⁵⁵ and Thaut et al,⁴⁹ we suggest that there is insufficient evidence for the superiority of any other particular approach.

Activities of Daily Living

Four of 16 studies investigated the effects of Bobath therapy on ADL (supplemental Table III)^{39,40,43,44,54} (see <http://stroke.ahajournals.org/>).

Best Evidence Synthesis

Four studies were included in the BES regarding the effect of Bobath on ADL. All 4 papers reached a PEDro score of ≥ 4 and were classified high-quality RCTs. The median PEDro score was 7 (range, 4 to 8).

There is some evidence for the effect of Movement Science-Based treatment on improving bathing skills in patients at 1 month poststroke.⁴³ However, only the study of Lum et al⁴⁴ showed superiority for robotic therapy. No BES could be classified for the superiority of any approach on ADL.

Health-Related Quality of Life

Only one study examined the effects of Bobath on HRQOL (supplemental Table III). In Langhammer and Stanghelle,^{39,40} Bobath was compared with the Motor Relearning Programme on patients with stroke over the course of their hospitalization. The Nottingham Health Profile was used to measure HRQOL at 3 months after hospitalization. No significant differences were found between both groups. However, there was a significant difference between men and women for both treatment groups suggesting that men perceived a higher HRQOL than women irrespective of treatment assignment (men median, 15; women median, 33; $P < 0.003$).

Best Evidence Synthesis

One study was found on HRQOL and was qualified as a high-quality RCT. Differences based on treatment modality were not found, but a significant difference in gender was revealed in favor of men. Because of the gender difference and only one relevant study on this subject, no BES was applied.

Cost-Effectiveness

One study³⁹ compared the cost-effectiveness in terms of length of stay in the hospital of Bobath and Motor Relearning Programme and observed a significantly shorter length of stay in the hospital in favor of the Motor Relearning Programme group (21 versus 34 days, $P = 0.008$). Although no formal economic evaluation was conducted, this marked reduction in length of stay is likely to generate substantial healthcare savings.

Best Evidence Synthesis

There was only one high-quality RCT on cost-effectiveness; therefore, no BES could be applied.

Discussion

The objective of the present systematic review was to evaluate the available evidence for the effectiveness of the Bobath Concept in comparison to other approaches in stroke rehabilitation. After conducting an electronic search, 16 relevant papers involving 813 patients with stroke were selected and analyzed. All papers reached a PEDro score of ≥ 4 and were considered high-quality RCTs.

Based on BES, this review found no evidence for the superiority of Bobath therapy or any other approach on sensorimotor control of the upper and lower limb, dexterity, mobility, ADL, HRQOL, and cost-effectiveness. Only

limited evidence was found for balance control in terms of symmetry of weight distribution over paretic and nonparetic side and overall balance (ie, Berg Balance Scale). Because of the limited evidence available, no BES was applied for the HRQOL domain and cost-effectiveness.

Methodological Considerations

Two previous systematic reviews of the Bobath Concept^{16,18} concluded that there was no proof for the superiority of Bobath as the optimal type of treatment. Now, 4 years later, additional RCTs have been published making a proper effectiveness analysis feasible based on available evidence from RCTs. However, methodological shortcomings in these studies such as inappropriate randomization and blinding procedures as well as dropouts need to be considered for bias resulting in false-positive or -negative results.

In the present review, BES needs to be considered in light of the limitations of the RCTs selected. Statistical pooling of effect sizes was not feasible due to methodological heterogeneity and variability in patient characteristics, outcome measures, and implemented intervention strategies. The number of patients enrolled in these individual studies was often insufficient resulting in lack of power and, as a consequence, increased risk of Type II error (ie, observing false-negative effects); only 8 of 16 trials in this review allocated >20 participants per group with total numbers of patients ranging from 21 to 120 participants. Most studies suffered from low treatment contrast; a valid comparison between the treatment and control groups was prohibited because often no control was implemented for the amount of attention given to both groups. Based on previous systematic reviews, Kwakkel et al⁶ and van Peppen et al^{23,56,57} found that the overall sizes of treatment effects were relatively small ranging from 5%⁶ to maximally 12%²³ in favor of the experimental treatment arm. These relatively small effects further increase the risk of Type II error. This calls for the implementation of large, preferably longitudinally conducted trials with repeated measurements. In particular, RCTs based on a repeated measurement design provide an excellent opportunity to study the natural course of stroke recovery while at the same time reducing the relative contribution of measurement error to demonstrate any additional treatment effects on the time-dependent recovery pattern of spontaneous neurological recovery after stroke.⁵⁸ A further consideration is the fact that not all studies are true comparative studies between approaches; 4 studies in this review reported comparison of alternative approaches as an adjunct to Bobath therapy (treadmill training,³⁸ Rhythmic Auditory Stimulation,^{49,55} and independent standing practice⁴⁷). Three of these 4 adjunctive techniques found significant effect in favor of the alternative group; however, it is possible that this treatment effect could also be attributed to a combined treatment effect.

Therapy Considerations**The Content and Intensity of Therapy**

Evidence from a recently updated Cochrane review of postural control and lower limb function poststroke¹⁷ suggests that a mix of components from different approaches is

significantly more effective than no treatment or placebo control. Thus, it is crucial to know which components or strategies have been applied in any therapy approach. This was a weakness of the RCTs in our review. There was a lack of description of the actual content of Bobath therapy; only 7 studies outlined the content of the Bobath Concept in more detail referring to specifically trained therapists, who selected interventions from specifically designed treatment protocols.^{39,43,46–48,53,55} However, the intervention described as Bobath, with the exception of Wang et al,⁴⁵ is often not recognizable as current Bobath practice. IBITA¹² and Raine^{10,11}, which have investigated the beliefs of expert Bobath tutors, both confirm that the Bobath Concept targets both impairments and functional task practice stating that successful goal acquisition in a given task must be practiced to improve efficiency of movement and promote generalization in everyday life. Another difficulty in finding any significant effect between approaches may be due to the large variability between studies and differences within studies in the intensities that were actually received by the patients. Moreover, the results of a systematic literature search suggest that more time dedicated to practice⁶ and more repetitive task training⁵⁹ are likely to generate small⁶ to modest⁵⁹ improvements in lower limb function. In fact, only few studies actually managed to provide the recommended intensity of treatment recommended by Kwakkel et al⁶ to show effect.

Theoretical Assumptions

Therapy based on the Bobath Concept aims to regain motor control and function of the hemiparetic side after stroke without promoting compensation.^{4,11,12} Facilitation of normal movement components (which includes strategies to maintain muscle and joint alignment) and task-specific practice using specific manual guidance have been identified as critical elements of the Bobath Concept.^{1,4,60} A more recent publication by Raine¹¹ states that the aim of therapy is to optimize postural and movement strategies to improve efficiency so that patients can achieve their maximum potential; the aim is not about achieving normal movement. Because the content of the Bobath Concept has changed over time, assumptions have been adapted and the content of each particular study's therapy is usually undefined, rarely described, and most likely variable; it is difficult to know what precisely constitutes this concept. However, what is known is that a number of original assumptions of the Bobath Concept show intrinsic weaknesses (see for critical reviews, references^{61,62}). Only some of these assumptions about recovery of motor control and function have been put to the test in research. Bobath therapists have assumed that a symmetrical weight distribution implies better postural control, but this perceived relationship between symmetry in weight distribution while standing and walking and balance has not been proven.^{56,63–65} For example, Kirker et al⁶⁶ found that standing patients with stroke are more stable when they keep their postural control over the unaffected limb. This finding suggests that the asymmetrical stance in hemiparesis may be necessary to compensate for muscle weakness,^{67,68} delayed muscle activation,^{66,69} synergistic-dependent activation patterns of mus-

cles,⁷⁰ and perceptual deficits.^{71,72} In other words, asymmetry does not necessarily imply decreased postural control and higher risks of falls.^{73,74} Excluding symmetry from the present analysis would render no BES for balance control.

Moreover, a number of longitudinally conducted studies suggest that improvement in balance control while standing occurs in most patients without significant anticipatory changes in electromyographic activation of hamstring muscles on the paretic side in response to rapid arm movement. Instead, recovery of functional balance can be accompanied with significant anticipatory changes on the nonparetic side.⁷⁵ In the same vein, de Haart et al showed that a reduction in postural sway and visual dependency while standing occurred without normalization of weight distribution toward the paretic leg.^{63,64} Finally, van Asseldonk and colleagues⁶⁵ showed that ground reaction forces and body sway measured during biped standing on a platform (that elicited continuous random movements) are difficult to explain by an active contribution of the paretic leg. Maintaining balance during perturbations of the platform heavily relies on the contribution of the nonparetic leg by shifting the center of gravity toward the sound side.⁶⁵

Another example relates to our understanding of recovery on walking ability. Kollen and colleagues⁷⁶ investigated the longitudinal changes in walking ability and found that changes in synergism of the paretic leg over time were only weakly associated with improvements in hemiplegic gait. In agreement with this observation, Kwakkel et al⁷⁷ showed in 53 patients with stroke that larger stride lengths on the nonparetic side contributed more to observed improvements in comfortable and maximal walking speed than measured kinematic changes on the paretic side.⁷⁷ Interestingly, in work reported by Bowden and colleagues,⁷⁸ some patients with severe hemiparesis approached normal walking velocities (>0.8 m/s), whereas their paretic leg contributed less than 30% to the total propulsion force, indicating that they were using compensatory strategies. Likewise, a number of recent longitudinally conducted studies showed that improvements in gait speed and walking ability after stroke were not significantly associated with a change in muscle activation of the paretic leg assessed by electromyography.^{79–81} In other words, changes in coordination patterns or muscle activation and synergies during recovery related to the affected side do not appear to explain observed improvements in gait after stroke.

These studies suggest that functional improvements are not only based on restoration of deficits, but, in many instances, on learning adaptive movement patterns. These adaptation strategies already start as soon as patients learn to accomplish functional tasks within the first weeks poststroke.⁵⁸ A recent focus group paper of expert Bobath tutors refutes this idea that “normal” symmetrical movement is a key feature of the Bobath Concept.¹¹ The expert tutors also acknowledge that compensation may be necessary but that therapy should not aim to promote compensation.^{11,12} This is a key question: does compensatory motor behavior really lead to worsening of functioning? A future research study could be designed to demonstrate if therapeutic interventions aimed at minimizing compensatory movements early after stroke lead to more

efficiency and higher accuracy in motor performance later during recovery. Research remains an issue for the Bobath Concept, although it has been helpful to publish both clinical therapists' interpretations⁴ and expert tutors' views of the theoretical assumptions underpinning the Bobath Concept^{10,11}; it must be remembered that having a plausible theory to explain how and why therapy is structured and delivered in a specific way does not constitute evidence; it is necessary to set up research trials to put these theories to the test.⁸²

Moving Forward

The key assumptions of the Bobath Concept have been adapted according to emerging evidence.¹² However, further exploration is required between these updated assumptions and currently available evidence of dose–response relationships in motor learning, time-dependency of neuronal and functional recovery, and task specificity of treatment effects. The Bobath Concept is a clinical reasoning approach; it should be regarded as only one of many tools available to a therapist to deal with individual deficits and opportunities for stroke survivors, especially for those in which recovery of functional motor control is feasible. Therapists in neurology base their assumptions about intervention on different philosophical perspectives, which determine how patients are assessed and treated.⁸² Therapists need to incorporate a wide range of strategies that are supported by the current evidence base into their treatment programs regardless of their philosophical origin.¹⁷ Combining elements from different approaches and evolving evidence from research findings may enable therapists to optimally capitalize on available treatment tools to deal with individual needs and challenges.

To improve realistic goal setting, a better understanding of the factors that predict a patient's ability to accomplish functional improvement is needed. Therefore, therapy should be based on up-to-date knowledge of evidence-based strategies as well as on knowledge of the time-dependent nature of recovery patterns.⁶ All therapists should be open-minded to evidence-based practice and receptive to new developments in stroke rehabilitation.

There is professional debate about the evidence base underlying the Bobath Concept. In the United Kingdom, the BBTA has allied itself with higher education institutes developing modules at the Master's level; BBTA continues to provide evidence-based courses underpinned by present-day knowledge of motor learning, motor control, and neural and muscle plasticity. BBTA advocates the use of evidence-based adjunctive treatments as appropriate for the patient, for example, strength training, mental practice, treadmill training, modified constraint-induced movement therapy, orthotics, and so on. The International Classification of Functioning is also used as a framework for ensuring the inclusion of comprehensive and standardized outcome measures for assessment and evaluation. The Netherlands has adopted a different perspective. Over a period of 18 months, all 22 Bobath instructors have adopted evidence-based practice based on the Dutch Physical Therapy Guidelines for Stroke.²³ It is their view that in line with the lack of evidence as well as major changes over time in our understanding of underlying

mechanisms about stroke recovery, which do not concur with the obsolete and constantly changing assumptions used to explain the Bobath Concept,^{61,62,82} a new evidence-based approach was warranted. Therefore, in effect, a new approach based on evidence-based guidelines and the improved understanding of mechanisms underlying adaptive motor relearning and mechanisms of functional recovery after stroke replaced the Bobath Concept. This new eclectic approach is referred to “neurorehabilitation-stroke” in The Netherlands. This endeavor was financially supported by a grant from the Dutch National Institute of Health (Zorg Onderzoek Nederland; ZONmw project no. 14.350.047) and facilitated over a 1-year course in which all instructors were also trained to select and apply the core set of measurement instruments recommended by the Dutch stroke rehabilitation guidelines and to predict individual functional outcome.⁵⁷

This systematic review has highlighted many methodological shortcomings in the studies reviewed. Future RCTs need to analyze the content of therapy and consider the intensity of intervention delivered in relation to the outcomes achieved. None of the studies within this systematic review of the effectiveness of the Bobath Concept documented the clinical problem-solving process used by Bobath therapists or the treatment strategies selected to enable patients to achieve their goals. When designing experimental trials to evaluate the Bobath Concept, care should be taken to incorporate up to date Bobath theory and practice using trained Bobath therapists. Therefore, until further high-quality RCTs are published, evidence-based guidelines, accepted rules of motor learning, and biological mechanisms of functional recovery rather than therapist preference for any named therapy approach should serve as a framework from which therapists should derive the most effective treatment.

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