Sensorimotor Integration for Functional Recovery and the Bobath Approach

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Bobath therapy is used to treat patients with neurological disorders. Bobath practitioners use hands-on approaches to elicit and reestablish typical movement patterns through therapist-controlled sensorimotor experiences within the context of task accomplishment. One aspect of Bobath practice, the recovery of sensorimotor function, is reviewed within the framework of current motor control theories. We focus on the role of sensory information in movement production, the relationship between posture and movement and concepts related to motor recovery and compensation with respect to this therapeutic approach. We suggest that a major barrier to the evaluation of the therapeutic effectiveness of the Bobath concept is the lack of a unified framework for both experimental identification and treatment of neurological motor deficits. More conclusive analysis of therapeutic effectiveness requires the development of specific outcomes that measure movement quality.

Keywords: motor control theory, rehabilitation, recovery, stroke, Bobath concept

Knowledge of motor control has increased over the past few decades but the translation of this knowledge to current clinical practice has not been fully realized. This has led to criticism of long-standing clinical approaches such as Bobath/Neurodevelopmental Treatment (NDT), based on the impression that these approaches are not founded on established principles of physiological function and motor control. Bobath therapy is a treatment approach used by therapists to help patients regain function and movement. The Bobath concept is a systems’ approach to movement reeducation that seeks to optimize sensorimotor function according to the capacity of the individual. Key principles of Bobath include a whole-person ecological approach and the avoidance of motor compensations to facilitate the potential reappearance of typical movement patterns (recovery) using sensory information from multiple sources. In this context, typical movement patterns are characterized by EMG and kinematic patterns similar to those that are observed in healthy individuals of the same age and gender who do not have musculoskeletal or neurological injury. The Bobath concept favors motor solutions that optimize the quality of movement while not permitting the system to find solutions that incorporate motor compensations (Bobath 1990; Howle 2002). The term motor compensation is used
when movements incorporate new motor patterns resulting from the adaptation of remaining motor elements or substitution by different muscles, joints or body segments (Levin et al. 2009).

The Bobath concept uses both automatic (e.g., postural adjustments and limb placing—see below) and cognitive processing (i.e., problem-solving). It focuses on patient-initiated, therapist-guided movement production with the engagement of the whole body where each part influences the whole and vice versa (Bobath 1990). The approach is mainly indicated for the treatment of patients with neurological disorders but it can be employed in other cases, including treatment of orthopedic problems, requiring movement reeducation. It was initially formulated in 1943 by Berta Bobath without concern about empirical physiological justification. Bobath was a physiotherapist and the development of the approach stemmed from her background as a remedial gymnast, her well-honed powers of observation and her analytical approach to movement analysis. She was acutely aware of and sought out neurophysiological evidence to justify her approach based on data from the physiological literature of the day and through consultations with her neurophysiologist husband, Karel. Admittedly, the state of physiological knowledge at the time was limited but nevertheless, the concept continued to evolve despite the lack of a clear understanding of its physiological underpinnings.

The transfer and application of basic science knowledge to many aspects of clinical practice such as the Bobath concept has been problematic for several reasons—the motor control literature is based on principles of movement and motor learning characteristic of the healthy nervous system; the motor control literature is confusing and at times contradictory; the use of terminology is not precise and includes jargon specific to particular subspecialties (e.g., biomechanics, robotics, engineering, neurophysiology). Due to these reasons, among others, the literature is often difficult to interpret by researchers and clinicians alike. In a recent review, Vaughan-Graham et al. (2009) provided an overview of basic science principles related to clinical practice within the framework of the Bobath approach to movement remediation. This review is an important step in the knowledge translation and application process, but does not go far enough in providing in-depth analysis of any specific principle of the Bobath approach.

It is not the intention of this review to present a detailed description of the Bobath concept. Instead, our purpose is to provide an in-depth review and critical analysis of the theoretical underpinnings of one of the key principles of the Bobath concept—how sensorimotor information from multiple sources is used by the central nervous system (CNS) to optimize functional performance. We will review the physiological evidence for the role of sensory input in movement production in the healthy and damaged CNS and discuss this evidence in light of current motor control theoretical frameworks including dynamical systems and equilibrium-point (EP) approaches.

It should be pointed out that despite all controversies between current motor control theories, there is growing understanding that sensory information plays a fundamental role in motor control, which is consistent with this key Bobath principle. This understanding has received growing support despite numerous demonstrations, starting from a classical work by Graham Brown (1911), that movement could be produced in the absence of proprioceptive feedback. These demonstrations resulted in the dominating view that the CNS basically programs
motor commands, i.e., electromyographic (EMG) patterns, required for movements whereas proprioceptive feedback is used to adjust these patterns depending on external conditions and required corrections. This view, however, is not fully justified by results of such experiments since deafferentation artificially reduces the control function of the CNS to a direct specification of motor commands, which is not the case when afferent information is available. A cautious approach to interpretations of deafferentation experiments is especially needed when human movement is considered: two well-studied patients with deafferentation (CF and GL) confirmed by appropriate neurological tests, are wheelchair bound and are unable to stand or walk without substantial assistance. In addition, even years after deafferentation, movements made by these individuals remain highly deficient (see the web site by Jacques Paillard devoted to deafferentation: http://jacquespaillard.apinc.org/deafferented). Thus, when considering different theories of motor control, clinicians should focus on those that take into account the fundamental role of sensory information.

**When Is Movement Considered Suboptimal or Abnormal?**

The healthy nervous system can involve different body segments to perform the same motor task. In more specialized terms, this capacity is associated with *redundancy* in the number of degrees of freedom of the motor apparatus (Bernstein 1967). For example, we usually move only the arm to reach an object placed within reach, but we can also perform the same reaching task while leaning the trunk forward or even while taking a step. We can move the hand directly to the object or along a curvilinear path, in order, for example, to avoid an obstacle. People with CNS lesions often lack the ability to perform movements in different ways (Mihaltchev et al. 2005). Thus, movement *deficits* or abnormal movement *can be defined as limitations in the range of motor patterns normally available to healthy individuals*. For example, when attempting to reach an object placed within arm’s reach, many stroke survivors may use abnormal movement patterns in the arm such as shoulder elevation and abduction and reduced elbow extension instead of shoulder flexion and elbow extension. This abnormal arm movement pattern is then accompanied by excessive recruitment of the trunk segment, a motor compensation, to be able to extend the reach of the arm (Levin et al. 2002; Michaelsen et al. 2004). Excessive compensatory trunk use is also observed when attempting to orient the hand for grasping (Roby-Brami et al. 2003; Michaelsen et al. 2004). By itself, the pairing of arm and trunk movement may not be considered as abnormal. What is abnormal, however, is the inability of patients to make arm reaches in the absence of trunk movement when trunk movement is not necessary, such as when an object to be grasped is within reach of the arm (Levin et al. 2002). This can be viewed as a limitation in the range of possible movement combinations and the presence of a restricted repertoire of stereotypical movement patterns (Twitchell, 1970). Thus, the term “normal” or “abnormal”, can refer to both individual motor actions and movements as well as to the ranges or repertoires of possible movement patterns. From this perspective, *the purpose of rehabilitation is to help patients regain, according to their potential, their full range of motor patterns*. 
The Bobath Concept and Motor Control Theories

The Bobath approach is based on both implicit and explicit assumptions about normal motor control and motor learning as well as some concepts of neurodevelopment. Traditional neurodevelopmental therapists take a top-down approach and suggest that the acquisition of movement and motor skills results from the maturation and experience of the CNS. In therapy, the focus is on eliciting and establishing typical movement patterns through therapist-controlled sensorimotor experiences (Bobath 1990; Bower 1993; Howle 2002), within the context of task accomplishment (e.g., stepping within the context of walking; Davies 2000; Panturin 2002). Conceptually however, the approach has evolved with the growth of knowledge in neuroscience and rehabilitation toward the placement of an even greater emphasis on function. Specifically, Bobath practice incorporates “task-oriented” movement that targets the learning of meaningful motor skills perceived as problematic by either the client or caregivers (Shepherd 1995; Howle 2002; Panturin 2002). Task-oriented approaches may be viewed as being based on the dynamical systems theory of motor development and motor control (Bernstein 1967; Gibson 1979; Thelen and Smith 1994; Kelso 1995) because of the underlying assumption, consistent with this theory, that performance emerges from the dynamical interaction between the performer, the environment and the task (i.e., see Shepherd 1995; Wagenaar and van Emmerik 1996; Butler and Darrah 2001). Like task-oriented therapy, the Bobath concept is a problem-solving approach to assessment and treatment. Bobath involves active learning processes in environments that enable the individual to learn to perform self-initiated actions within naturally occurring constraints (Thelen and Smith 1994; Panturin 2002; Vaughan-Graham et al. 2009). An important concept in this problem-solving approach is that it permits the system to find the best set of motor solutions for a given task. Because of the redundancy of the system, motor control theory suggests that there may be more than one motor solution, in terms of the interjoint movement pattern, for a given task (Latash et al. 2004). Thus, the Bobath concept is consistent with dynamical and EP theory in that the CNS is not concerned with the selection of an optimal movement trajectory but that desired trajectories emerge from the interaction between properties of the neuromuscular elements and the environment within spatial boundaries predetermined by neural control centers (see below; Feldman and Levin 2009).

One of the main techniques used in the Bobath approach is ‘placing’, which is the ability of the patient to move his/her limb and trunk actively in response to the segment being moved by the therapist (Bobath 1990; Howle 2002). This ability is thought to be an automatic or subconscious process in which the CNS receives afferent information from the moving limbs and trunk and responds by appropriate active motor output (Bobath 1990). Thus, the Bobath principle of ‘placing’ encourages the motor system to be actively involved in problem-solving (Shepherd 1995; Latash and Anson 1996; Newell 1996).

Another Bobath technique that uses similar principles of sensorimotor integration is ‘sensory guided muscle activation’ in which the therapist assists the patient to stabilize a proximal body segment or joint in the correct orientation before and/or during active movement of a distal effector. Assisted joint orientation is thought to provide the CNS with desirable sensory information about joint position and movement and uses biomechanical principles of optimal joint alignment to facilitate
muscle contraction. For example, for the reeducation of a reaching movement in which the normal scapulo-humeral rhythm is disrupted, a Bobath therapist may encourage the contraction of the key muscles by placing his/her hands on or around the scapula. Hand placement encourages proper scapular alignment by providing cutaneous input over appropriate scapular stabilizers while the patient performs functional movements with the upper limb (Figure 1). Subsequent arm movements

Figure 1 — Example of the Bobath principle of ‘sensory guided muscle activation’ in which the therapist assists the patient to place the scapula in the correct alignment while the patient performs reaching movements.
performed by the patient provide more optimal proprioceptive feedback from the target muscles. In this technique, the Bobath therapist attempts to encourage active contractions and enlarge the shortened spatial range in which they can be produced. One explanation for why this technique may result in better active movement comes from recent studies on spasticity and voluntary muscle activation based on the notion of threshold control in the EP theory of motor control.

According to EP theory, the notion of threshold position control (Matthews 1959; Feldman & Orlovsky 1972; Nichols & Steeves 1986; Capaday 1995) suggests that movement is produced by shifting, in a feed-forward manner, the articular position at which muscle recruitment begins (Feldman 2009). Specifically, proprioceptive feedback produces position-dependent motoneuronal facilitation mediated by muscle spindle afferents. For a single muscle or muscle group, this results in an increase of the membrane potential until the electrical threshold ($V_+$) for motoneuronal recruitment is reached (Figure 2A). The electrical threshold is achieved at a certain muscle length or joint angle called the referent or threshold angle, $R_+$, that due to sensory information (afferent feedback), is linked to spatial aspects of the body—i.e., muscle length, limb position and a specific whole body configuration. It has also been shown that mono- and polysynaptic influences of different descending systems on $\alpha$- and/or $\gamma$-motoneurons produced independently of afferent feedback shift the spatial threshold (for review see Feldman 2009). Shifts in spatial thresholds underlie intentional movements in humans (Asatryan and Feldman 1965) and are mediated by descending excitation and inhibition evoked by direct or indirect brain and brainstem electrical stimulation (Feldman and Orlovsky 1972; Nichols and Steeves 1986). Recent data obtained in humans demonstrated the involvement of corticospinal pathways in shifting spatial thresholds (Raptis et al. 2010). These authors showed that corticospinal pathways are also involved in muscle relaxation (see also Sowman et al. 2008). By changing spatial thresholds, descending systems predetermine the special “frame of reference” within which the neuromuscular periphery is constrained to work without indicating how it should work—the activity of neuromuscular elements emerge and is graded depending on the difference between the actual position of the body segments and their threshold positions predetermined by the brain. CNS damage leads to altered activity in descending systems resulting in increased resting membrane potentials (Figure 2B, vertical arrow). This results in a decrease in the upper spatial threshold for muscle activation (Figure 2B, $R_+$). In other words, the subject cannot relax muscles in the joint range that exceeds this upper limit (from $R_+$ to the upper limit of the biomechanical range ($\Theta_+$)). Accordingly, active or passive movement of the joint in this range, causes early undesirable velocity-dependent reflex-mediated muscle activation, otherwise known as spasticity (Levin and Feldman 1994).

Estimations of the specification and range of regulation of tonic stretch reflex thresholds in patients with upper limb spasticity have revealed articular ranges of the elbow and shoulder during slow point-to-point movement in which muscles can contract normally (i.e., with reciprocal muscle activation patterns), and other ranges in which reciprocal muscle contraction is not possible and only muscle coactivation can occur, which is considered an abnormal pattern of muscle activation for this type of movement (Levin et al. 2000; Musampa et al. 2007). Figure 3 shows examples of experimentally determined joint ranges in which active control of elbow flexor and extensor muscles is or is not possible in two patients with hemiparesis.
In the patient shown in Figure 3A, when the elbow was initially placed at a joint range in which the CNS could regulate thresholds, the patient was able to generate elbow extension and flexion torque and move the elbow for a few degrees in either direction using a typical reciprocal pattern of muscle activation (‘control range’).
Figure 3 — Patterns of muscle activation recorded from two patients with hemiparesis during voluntary elbow flexion (A) and extension (B). Bottom panels show the biomechanical range of the elbow extending from 30° to 180° and the locations of the upper spatial limits (R+), (stretch reflex thresholds) for elbow flexors (Rf) and elbow extensors (Re) in each patient. In A, elbow flexion made from the initial position of 90° located within the ‘control zone’ was accomplished by reciprocal muscle activation (activation of the flexor agonists without coactivation of the extensors). In B, elbow extension made from the initial position of 40°, outside of the ‘control range’ and in the spasticity range, was accomplished by excessive coactivation of the antagonist flexor muscles. Adapted with permission from Levin et al. *Brain Res.* 2000;853:352–369.
In the patient shown in Figure 3B, however, when the elbow was initially placed beyond the angle at which the tonic stretch reflex became active for the antagonist muscles, only agonist/antagonist coactivation could occur and the patient was not able to finely control elbow movement. This concept, based on the idea of threshold position control, explains why patients may be able to control movements in some joint ranges and not in others, as well as the occurrence of muscle weakness (Mihaltchev et al. 2005; Musampa et al. 2007; Calota et al. 2008).

The concept of ‘control ranges’ is likely exploited in the Bobath concept. Returning to the example of scapular stabilization shown in Figure 1, based on knowledge of that patient’s muscular ‘threshold ranges’, the therapist can place the limb in a configuration in which the patient can produce sensory-guided muscle activation in a given biomechanical range. Active control can be improved by increasing the size of the ‘threshold control range’ via plastic mechanisms, leading to better recovery of typical movement patterns. In individuals with neurological deficits, the recovery of typical movement patterns can also be understood based on modern concepts of how sensory experiences drive CNS plasticity (Xerri et al. 1998). Moreover, the principles used in the Bobath concept to achieve recovery are similar to those identified by stroke researchers that take advantage of the system’s plasticity (Kleim and Jones 2008). These include the encouragement of variable and repetitive practice of the involved limbs, practice of challenging and/or novel activities that provide appropriate sensory feedback, engagement of the learner and problem-solving.

**Sensorimotor Integration in Movement Control**

One of the key concepts of the Bobath approach is the contribution of sensory inputs for motor learning and for shaping motor output (Gjelsvik 2008). There is ample evidence from the motor control literature for the essential roles of sensory information in guiding motor output (e.g., Gandevia and Burke 1992; Schmidt and Lee 2005). For example, it is well established that movements made by patients with partial or complete sensory loss lack precision and coordination (Bard et al. 1992; Levin et al. 1995; Stenneken et al. 2006). Movements in deafferented patients with complete large fiber sensory loss who have no cutaneous sensation or proprioception are imprecise and characterized by dysmetria (Forget and Lamarre 1995; Lajoie et al. 1996), even in the presence of visual information (Bard et al. 1999). The loss of sensory information has also been cited as a reason for the lack of awareness of self-movement in deafferented patients (Fourneret et al. 2002). These movement and recognition deficits can be explained in the context of the essential role of sensory information in the specification and regulation of motoneuronal activation thresholds according to the EP theory described above (Feldman 1986; 2009). When proprioceptive information is absent or altered following injury or disease, the nervous system is unable to specify the origin point, or referent position of the spatial frame of reference for recruitment of motoneurons, leading to abnormal movement.

Another example from the motor control literature of the importance of sensory input in motor organization is the powerful effect of light touch applied to or by the finger in reducing postural sway in older adults, adults (Kiemel et al. 2002; Baccini et al. 2007), children (Metcalfe et al. 2005) and patients with gait disorders (Perez
et al. 2009). The dramatic improvement in postural stability with light touch may be explained as an enhancement of sensory estimates of self-motion (Kiernel et al. 2002) or from a motor control perspective, as a reference point for the internal body schema proposed by Paillard (2005) and reformulated as the referent body configuration by Feldman and Levin (1995; 2009). Moreover, since the haptic information originates from a point that is stationary in the environment, it places the body reference frame within a relevant frame associated with that environment. The environmental frame of reference is thought to be formed when the ability to walk emerges in infancy (Feldman and Levin 2009). This suggestion is consistent with the finding that light touch stabilizing sway occurs around the first months following the transition to independent locomotion in infants (Barela et al. 1999).

Yet another example of the importance of sensory information in movement control is the activation of dynamic touch receptors of the thumb and finger pads in ensuring the maintenance of fingertip forces for stable and secure precision grasping (Monzee et al. 2003; Hermsdorfer et al. 2008). This control can also be related to the specification of the reference frame for interdigit aperture and the notion that grip force emerges from the difference between the actual aperture defined by the size of the object and the referent aperture specified by the brain (Figure 4; Pilon et al. 2007).

Aside from sensory loss, altered sensory input also results in movement disruption, such as postural instability when vibration is applied to the soles of the feet (Kavounoudias et al. 2001), or the change in gait speed following neck muscle vibration (Ivanenko et al. 2000). Similarly, altered articular afferent information may decrease γ-motoneuronal excitability, causing proprioceptive deficiencies. Joint damage may decrease α-motoneuronal excitability reducing voluntary activation (Hurley 1999). On the other hand, some studies have reported the beneficial effects of added noise for sensory detection based on the concept of stochastic resonance.

Figure 4 — Example of grip force production based on a shift in the referent position (R). A. The actual finger aperture (Q) is limited by the shape of the object grasped. The referent aperture (R) specified by the nervous system is smaller than Q. The greater the difference between Q and R, the higher is the grip force. B. The fixed Q aperture is shown by the vertical line (isometric condition). The referent aperture, R, is smaller than the actual, Q, aperture. The point of intersection between the two configurations is the actual grip force at the point of contact of the fingers with the object. By decreasing the R, subjects can increase the force. Adapted with permission from Feldman et al., Progress in Brain Research, 165:267–281, 2007.
For example, Priplata et al. (2005) found that postural sway was reduced in patients with stroke when subsensory noise was applied by vibrating insoles to the soles of the feet during quiet standing. These are but a few examples of how sensory information is essential for the organization of movement not only at the segmental level but at multiple levels of the CNS. One of the explanations for multisegmental movement organization is the role of segmental sensory inputs in the modulation of reflex excitability in heteronymous muscles in both healthy subjects (Meunier et al. 1994; Nichols 1999; Marchand-Pauvert et al. 2005; Nichols and Ross 2009) and in stroke survivors (Sangani et al. 2007).

For motor relearning, therapists in general and Bobath therapists in particular often use sensory inputs in the form of tactile information from the hands to shape movement while removing manual guidance when patients become capable of self-generated movement. As in the example shown in Figure 1, by proper placing of the therapist’s hands, it is thought that a therapist can nonverbally guide a patient to move the limb in the desired direction. Physiologically, it is well-documented that cutaneous and other sensory signals can modify motor output. For example, H-reflexes in the lower limb can be modulated by cutaneous afferent input evoked by electrical stimulation (Levin and Chapman 1987; Chandran et al. 1988). The cutaneous information provided by the touch of the therapist’s hands may also modify muscle activation in the same way as the tuning of spatial motoneuronal thresholds produced by exteroceptive mechanical (vibration; Feldman and Latash 1982) or electrical stimulation (Feldman and Orlovsky 1972). Thus, foundations for the principles of sensory guidance of movement production, presumably via threshold regulation, can be found in the physiological literature.

Integration of Posture and Movement

The view that posture and movement are controlled by separate control mechanisms has dominated the study of motor control either out of convenience or tradition. However, rehabilitation approaches such as the Bobath approach evaluate and treat movement and posture problems together. The EP and dynamical approaches to motor control suggest that movement is not a separate state from posture of a segment or of the whole body (Bernstein 1967; Feldman 2009). According to the EP theory, postures are associated with an equilibrium state or referent posture of the body interacting with the environment (Figure 4). In motionless states, muscle and external forces are balanced, maintained by tonic motor activity, while the same system gives rise to movement by shifts in the reference frame (Feldman et al. 2007; Feldman 2009).

The EP theory is the only approach to motor control that solves the posture-movement problem described by von Holst and Mittelstaedt (1950). Briefly put, von Holst and Mittelstaedt (1950) observed that postures were maintained by mechanical and reflex responses to deviations from that posture. In other words, when holding an object with an outstretched arm for someone else to take, if one’s arm is suddenly pushed away from the initial position, the arm returns to the initial position through a combination of mechanical and reflex responses. This combination is called ‘posture-stabilizing mechanisms’ (Ostry and Feldman 2003). On the other hand, these mechanisms do not resist limb displacement when movements to a new position are made voluntarily. The question of how the system manages to do
this is the essence of the posture-movement problem. Von Holst and Mittelstaedt (1950) emphasized that the idea of suppression of reflex mechanisms conflicts with experimental data showing that reflexes can be active in any stationary and transitory limb position. A solution is offered in the EP theory as follows: by shifting the threshold position, the system resets (“re-addresses”) posture-stabilizing mechanisms to a new posture so that the initial posture appears to be a deviation from the new posture. Thus, instead of posture-stabilizing mechanisms resisting deviations from the initial posture, these same mechanisms are used to drive the limb to a new posture. In a detailed review, Feldman (2009) concluded that alternative models of motor control (e.g., internal model, force control model, efference-copy), do not provide a solution for this fundamental problem in motor control. The solution to the posture-movement problem offered by the EP theory is consistent with the Bobath concept that posture and movement are inextricably linked.

The integration of posture and movement is illustrated by studies of postural adjustments when subjects made voluntary arm or leg movements (Aruin and Latash 1995; Hodges and Richardson 1997; Hodges et al. 1999). For example, self-triggered arm movements were associated with anticipatory postural adjustments in muscles of the trunk and lower limbs indicating that postural adjustments always precede active movement (Aruin and Latash 1995; Hodges et al. 1999). The choice of the component movements of a task is related to the final goal of the action and the movement capabilities of the person. For example, when driving a car and planning to make a right turn at the next intersection, the driver grasps the wheel so that the hands will be in a comfortable position at the end of the turn. Similarly, in patients with stroke, reaching movements normally requiring only extension of the arm joints in healthy individuals, can incorporate additional movements of the trunk so that the hand can be positioned in a better orientation for grasping (Michaelsen et al. 2004). The concept of the interrelationship between movement and posture is well-exploited in the Bobath approach. For example, the action of getting out of bed from side lying is a dynamic activity that includes stabilization of postures in lying, sitting and standing while movements are made in sequence by the trunk and all four limbs.

**Effectiveness of Bobath Interventions for Motor Recovery in Stroke**

In view of its motor control underpinnings, determination of the effectiveness of Bobath interventions should necessarily include measures that target movement quality. However, recent reviews have not been able to draw definitive conclusions about Bobath treatment effectiveness (Paci 2003; Luke et al. 2004; Kollen et al. 2009). This may be due to two factors. First, the intervention described as Bobath is not always consistent with traditional Bobath practice (Raine 2006). Functional improvements reported are not always based on restoration of typical movement patterns but often include the use of adaptive or compensatory movements (Kollen et al. 2009). Second, most studies have not measured treatment outcomes at the appropriate motor level. Since a major emphasis of the Bobath concept is on the restoration of the quality of movement, treatment effectiveness should be measured within the same context. Outcome measures should thus target the quality of task
performance at the level of the basic muscle and/or motor patterns employed for that particular task rather than only at the level of task completion (Levin et al. 2009). To better assess treatment effectiveness therefore, measures should target changes in impairment within the theoretical context of modern approaches to motor control.

**Conclusions**

Understanding the theoretical underpinning of motor control and sensorimotor recovery may lead to better understanding of the Bobath concept. Derived from intuitive assumptions about motor behavior, this foundation of physical neurorehabilitation has not been heretofore subjected to an in-depth analysis of the motor control concepts on which it is based. Some of the key concepts of the Bobath approach are consistent with the physiological principles of sensorimotor integration and control processes such as those described in the dynamical systems approach and the equilibrium-point theory. Bobath therapy likely implicitly exploits these principles of motor control to facilitate motor recovery. Recognition of these principles by Bobath therapists may promote the development of more accurate assessment procedures to determine treatment effectiveness.

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**References**


