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COORDINATING TRANSITIONAL MOVEMENTS AND BREATHING IN PATIENTS WITH NEUROMOTOR DYSFUNCTION

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A young child with cerebral palsy, an older man with hemiplegia, a middle-aged woman with a head injury, all try unsuccessfully to roll over in bed. In addition to having neuromuscular deficits, these patients all have something else in common: they breath-hold as they try to move. For patients like these, maintaining posture is often easier than transitioning. They can maintain sidelying, but they cannot roll over. Similarly, they can maintain sitting, but they cannot transition in-and-out of sitting. What happens during these transitional periods of movement that makes patients with neuromuscular deficits less likely to be successful than persons without deficits?

The first part of this article will address this question using theory-driven problem solving to develop a picture of how the coordination of transitional movement and breathing becomes dysfunctional. Understanding how the interaction of these systems becomes competitive rather than complimentary will assist with deriving approaches for intervention. The second part of this article will suggest treatment strategies for the patient who's breathing and movement are competitive processes. The focus will be on treating the pulmonary and neuromotor systems interactively to maximize the coordination and function of both.

PART I: THEORY-DRIVEN PROBLEM SOLVING

An interactive systems approach to treatment of the patient, who breath-holds when attempting to move, necessitates identifying when and how the coordination of movement and breathing becomes dysfunctional. A *dynamic systems* perspective is helpful in this problem solving process. *Dynamic systems* theory has as its premise that motor behavior emerges from the self-organized interaction of multiple subsystems within the individual, the requirements of the functional task and the environment (Thelen, 1989). The application of this theoretical approach to the problem of coordinating breathing and movement can be clarified by defining the interaction of interest as simply the interaction between the motor task and the individual. The task consists of the motor requirements to transition from one posture to another, and the individual will be considered relative to the contributions and constraints of his or her neuromotor and ventilatory systems.

Under conditions of optimal neuromotor control, the emergent behavior should be an efficient coupling of movement and ventilation (Moerchen, 1994). However, patients often breath-hold to maintain a posture and are consequently unable to transition because movement and ventilation are in conflict rather than being coordinated. Again, a theoretical perspective is helpful in seeking to understand this problem. According to dynamic systems theory, motor behavior is continuous and time-based, where the time scale can be defined by the question or behavior of interest (Smith & Thelen, 1993). For our question about how the coupling of ventilation and transitional movement might become dysfunctional, the time scale can be defined as time t, time $t{+}1$ and so on, denoting a starting point (time t) and subsequent intervals. That is, time t will reflect the posture or motor behavior just prior to time $t{+}1$, at which point

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the task of transitioning requires dynamic control. It seems clear that being dynamic at time *t* will allow a continuity and efficiency of movement as the system changes from time *t* to time *t+1*. In contrast, breath-holding and the consequent loss of adaptable, dynamic control will lead to discontinuous and inefficient movement. If the patient is *stuck* in a posture at time *t*, then achieving the dynamic control or systems adaptability required for movement at time *t+1* will be impaired.

What might lead to the *stuck* posture at time *t*? One possible answer is a conflict between isotonic and isometric demands on the neuromotor system. If *stuck* is defined as the isometric holding of a posture, then the shared musculoskeletal resources for ventilation and trunk control must be considered. The coordination of breathing and movement is an interactive process based on anatomy and shaped by the motoric and metabolic (oxygen) requirements of the task at hand. To augment or to achieve postural control, the patient may use the muscles of the external chest wall (intercostals, diaphragm, and abdominals) to stabilize the trunk by breath-holding, where breath-holding is an isometric pattern. Thus, the muscles of ventilation function as trunk stabilizers (Epstein, 1994). In this case, the dynamic ability to transition between postures is limited by the breath-holding and the isometric contraction of the trunk that had been used to maintain the previous posture (at time *t*). Even if the extremities are able to move and initiate the movement (as in rolling or coming to sitting), the *stuck* trunk will interfere with the successful and efficient completion of the transition. If transitional movement does occur (at time *t+1*), thus overcoming the lack of dynamic movement at time *t*, movement is often discontinuous requiring great musculoskeletal effort and increased oxygen consumption.

Dynamic systems theory suggests that the motor behavior that emerges from the self-organization of relevant systems is the "best solution" based on these systems at that defined point in time. Clinically, this is meaningful in that it promotes a theoretical willingness to see atypical movement as an innovative strategy based on an underlying atypical neuromotor system (Darrah & Bartlett, 1995). However, when the best possible neuromotor solution at time *t* interferes with the system's adaptability at time *t+1*, a new, more dynamic solution is needed. Breath-holding is an example of a mechanism that is not adaptable as the system moves from holding a posture at time *t* to transitioning to another posture at time *t+1*. Hence, the patient's self-organization of a more dynamic motor solution needs to be the goal of intervention.

response. For example, the isotonic process of inhaling promotes isotonic trunk extension by opening the anterior chest wall and increasing extension of the upper thoracic spine (Crosbie, 1985; Mellin, 1987). The isotonic process of exhalation does the reverse, collapsing the anterior chest wall and causing relative isotonic flexion of the upper thoracic spine. With this natural coupling in mind, analysis of two simple transitional movements follows: rolling and coming to sitting.

Rolling from supine to sidelying can be achieved using trunk extension or trunk flexion. Using the concept of pairing complimentary ventilatory and movement processes, a rolling pattern that utilizes trunk flexion should be paired with exhalation. Likewise, a rolling pattern that utilizes trunk extension should be paired with inhalation. Thus, the movement-ventilatory behavior that should be encouraged in this transitional activity is one that matches the natural isotonic needs of the trunk (rolling over) with the isotonic needs of breathing (active inhalation or exhalation). In contrast, the breath-holding used by our patients while attempting to roll is isometric and conflicts with the isotonic requirements of this activity.

Similarly, if the motor task requires pushing up to sitting from sidelying, the trunk pattern that works most effectively for a given patient, be it trunk flexion or extension, should be paired with the ventilatory phase that is complimentary rather than competitive. If the trunk is primarily moving with flexion, use expiratory maneuvers such as blowing out, talking, singing or pursed lip breathing. If the trunk is primarily moving in extension, use quick inspiration (cued verbally or with an audible inhalation) to facilitate upper chest breathing, which more actively recruits upper thoracic extension. This coordinated interaction

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PART II: TREATMENT STRATEGIES

Intervention for the patient who holds breath when attempting to move should focus on how and why that patient's obligatory use of this mechanism emerged as a motor behavior in the first place. Treatment strategies should wed the ventilatory and neuromotor systems to promote synchronization of these systems rather than competition between them. That is, the function of one system can be used to augment the function of the other, hence, the concept of treating the two systems interactively. Three strategies for this interactive systems approach will be described.

Pairing isotonic contractions of the movement system with isotonic contractions of the ventilatory system: Transitional movements should be paired with specific breathing patterns that reinforce the desired overall movement pattern (Massery 1996a; 1996b; 1994). The intent here is to minimize the difficulty of moving from isometric holding/breath-holding at time *t* to the need for dynamic movement and an isotonic trunk at time *t+1*. If breathing and movement are coupled in treatment, the competition for muscular resources will yield to a more appropriate interaction of the two systems, which should result in a more successful motoric

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between the pulmonary system and the neuromuscular system enables both systems to contribute to more successful postural transitions.

Pairing concentric and eccentric maneuvers of the trunk with concentric and eccentric maneuvers of the desired movement: Consider an elaborated example based on the problem of breath-holding during movement. Reaching up while seated in a wheelchair, the patient with neurological impairments may demonstrate breath-holding, inadequate shoulder flexion and decreased upper thoracic extension. The desired movement of reaching up is concentric in nature; breath-holding is not. Thus, the emergent motor behavior fights itself; *t* and *t+1* are markedly discontinuous.

Treatment, in this case, should pair inspiration, which is concentric in nature, with the concentric motor task of raising the arm. Similarly, for the reverse action of controlling the return of the arm to the lap, the patient should be cued to pair eccentric control of the arm with eccentric breath control such as counting out loud, singing, pursed-lip breathing or uttering a prolonged "s" or "z" sound. The ventilatory and movement processes will thus be in-phase with each other and will thereby reinforce each other.

Consider also the *sit-to-stand* and *stand-to-sit* transitions that are fundamental to upright movement control. Moving to standing is a concentric activity, incompatible with the isometric nature of breath-holding. To achieve an in-phase relationship of breathing and movement, pair the trunk motions of this transition with the complimentary phase of ventilation. Initially, have the patient exhale when leaning forward, to coordinate breathing with the trunk flexion phase of the sit-to-stand transition. Then, pair active inhalation with trunk extension to complete the transition to standing. Whereas sit-to-stand transitioning is concentric, returning to sitting is eccentric and should be paired with eccentric exhalation to optimize the movement-ventilation interaction.

An additional treatment option that is consistent with an integrative systems perspective is to reinforce the coupling of ventilation and movement: Voss and Knott reinforced in their teachings of Proprioceptive Neuromuscular Facilitation that "the eyes lead the movement" in all patterns of exercise (Voss 1966, Knott & Voss 1968). If the eyes lead movement in general motor activities, it follows that they may also be used to lead and reinforce breathing patterns. Thus, the use of vision to initiate the response may be beneficial to interactive systems treatment strategies aimed at reducing the discontinuous nature of movement from time *t* to time *t+1*.

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Eye gaze upward is associated with trunk extension and upper extremity reaching, simply because we look in the direction that we reach. Given that reaching upward involves both trunk extension and concentric movement, inspiration would logically be paired with an upward eye gaze. Alternatively, a downward eye gaze would be associated with exhalation such as when reaching down to the floor, flexing the trunk or using any eccentric maneuver to control the rate of descent of the trunk toward gravity.

The effective and ineffective coupling of the visual-movement-ventilatory systems can be demonstrated by deliberately manipulating the pairing of these systems to produce the types of conflicts and interference that patients experience in their attempts at movement. The following examples are provided so that you can feel these relationships for yourself. First, while seated looking straight ahead, gaze upward as high as you can and blow out maximally (move only your eyes, not your head). Now, gaze downward as far as possible, moving only your eyes, and breathe in deeply. Was it difficult? This time, pair these systems with their natural partners. Again with your head held still and moving only your eyes, gaze upward as far as you can while taking a deep breath. Is your inspiration easier when gazing upward than when you were gazing downward? You should be able to feel the same benefit of natural systems pairing or integration when you gaze downward and exhale. The importance here is that visual-motor systems can be paired effectively with breathing to enhance the coordination of both systems.

Now, put it all together. Demonstrate for yourself the effectiveness of using treatment strategies that incorporate complimentary coupling of ventilation, postural movement and visual input.

First, attempt the transitional movements described in this article while purposely mismatching the interactions of the visual-movement-ventilation systems. This will cause the ventilation and movement needs of the task to compete for muscular resources, rendering the motoric outcome less successful. Specifically, try transitioning from sit to stand using a valsalva (breath holding) maneuver.

> ***With our sights set on function, breathing is a natural approach to sustaining movement!***

Did you naturally stop in a slightly flexed posture? Now try it with more optimal coupling of the visual, motor and ventilation systems. Blow out and look down as you initiate the trunk flexion phase of coming to stand. Then stand up and look up as you purposefully take in a quick, deep breath.

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Do you feel the difference? Are you more fully extended in stance than you were when you used a breath-holding strategy? Did it take less effort? The answer should be yes. Similarly, return to sitting, using the breath-holding strategy that our patients use. How controlled was your descent? Did you "fall?"

Now try this again, transitioning from stand to sit while also looking downward and counting out loud to five. Did you descend more slowly and with more control? Our patients fail to do this automatically and often adopt strategies that reduce the adaptability required for controlled, successful and safe movement. Establishing in-phase coupling of systems functions through integrative approaches to treatment will clearly help our patients gain more dynamic control of their movement.

CONCLUSION

The key to successful treatment of patients who have difficulty coordinating transitional movements and breathing has been identified and developed throughout this article as inherent to the nature of the problem itself: The interaction between systems. The coordination of shared muscular resources must occur so that efficient breathing and dynamic trunk control can co-exist. The anatomical demands of the trunk supports that this coordination must be treated through an interactive systems perspective to achieve the complimentary coupling of ventilation and postural movement. Additionally, the coupling of ventilation and movement can be reinforced using visually-guided movement that is in-phase with the ventilatory phase. Theory-driven problem solving was presented to support the idea that compensations in one system will impact function in an interrelated system. Similarly, the dynamic function of all systems at time *t* and *t+1* will enhance the continuous rather than discontinuous evolution and adaptation of the patient's movement solutions. With our sights set on function, breathing is a natural approach to sustaining movement!

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