Emerging Concepts of Posture and Alignment

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Dance educators have been posing questions and theories about the alignment of the body for centuries. In *The Life and Works of John Weaver*, Ralph[50] includes lectures by Weaver, written in 1721, in which he describes good posture for the dancer. Blasis[5] first published *An Elementary Treatise Upon the Theory and Practice of the Art of Dancing* in 1820, in which he expounds in detail about the correct placement of the segments of the dancer's body. By the 1900s these concepts of alignment were becoming extended, and detailed discussions of the importance of teaching proper alignment began to appear in the literature.[32,34]

The simplest and perhaps most common approach to this issue is one familiar to all dance educators, viewing the body in erect quiet stance. The dancer is observed from the side, and an imaginary "plumb line" is dropped from the top of the head down to the feet to assess how closely the centers of the various body segments and joints (head, shoulders, rib cage, hips, knees, ankles) approximate this line. The dancer is also observed from the front and back to check the bilateral symmetry of the body. What information or insight does this process of assessing alignment in stance yield? And how does this relate to what occurs once the body is in motion? Does the vertical placement of the body in quiet stance prepare it for the dynamic moment-by-moment adjustments needed to maintain equilibrium as the body moves in space, continually challenged by disturbances to balance? And how much of a dancer's balance and alignment is volitional effort, versus unconscious neural activation of muscles? If it is the latter, can these postural neuromuscular responses be enhanced through training?

It is easy to assume that static or quiet stance is a posture that is motionless and therefore does not require moment by moment muscular adjustments. However, Hellebrandt and colleagues[25] demonstrated that vertical, standing posture is not static, but rather it is movement occurring on a stationary base, referred to as postural sway. All postures of the human body, whether in quiet stance or moving through space, require ongoing muscular effort and adaptation. The somatic practices[1,2,19,24,56,57] explore the idea that alignment is dynamic and controlled at a neural level. The studies in the field of motor learning and motor control examine posture as an ongoing process of neuromuscular responses to disturbances, or perturbations, to balance.[3,6,7,10,13,14,17,26,45,54,63]

For the purposes of this writing, static vertical alignment is defined as a view of skeletal placement along a plumb line, viewed from the side, with the body segments stacked on the line of gravity in a non-locomotion stance, and with the weight evenly distributed between the feet. This can be considered a neutral "home base" for the body. Although it is not truly "static," this terminology is used to differentiate this idea of alignment from that of dynamic alignment. Dynamic alignment is defined as an ongoing process of neuromuscular postural responses occurring at an unconscious level, and can refer to the body in stance or in motion, in a variety of conditions. The purpose of this article is twofold: (1) to review, examine, and combine these various perspectives on posture and alignment; and (2) to propose training and research approaches suggested by emerging concepts.

STATIC VERTICAL ALIGNMENT

In the 1966 edition of *Kinesiology: The Scientific Basis of Human Motion*, Wells[60] defends the practice of assessing the alignment of subjects in the erect standing posture. She states that while this position is of little importance in and of itself, it is important as "the point of departure for the many postural patterns assumed by the individual, both at rest and in motion . . . its importance is in direct proportion *to the extent to which it represents the individual's habitual carriage* [emphasis hers]" (p. 391). Past and recent studies have used static vertical stance as a way of assessing alignment in dancers.

Woodhull-McNeal and colleagues[62] analyzed the alignment of thirteen female college dancers in four common dance positions (parallel first, and turned out first, third, and fifth) by photographing the dancers from the side, and then measuring distances between bony landmarks, including ankle, knee, hip joint, pelvis, shoulder, and ear. The measure of best alignment was represented by values coming closest to being in a straight line. Results of this study indicated that alignment in turned out first was significantly closer to a straight line than the other three dance positions. Additionally, anterior pelvic tilt was significantly greater in fifth position than the other three positions. This suggests that alignment is variable by condition.

Fairweather and Sidaway[18] conducted two studies observing alignment in quiet stance. The first study used the Wickens-Kiphuth method for alignment analysis. This system

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involves attaching rods to particular spinal landmarks, taking photos of the subject from the side, and then drawing connecting lines between dots on the photos. These lines are then used to calculate various misalignments, assessed in quiet stance. Their second study used a dynamic motion analysis system, Peak Performance, but the measurements were still taken only in quiet stance.

The first study involved 15 physically active high school males with histories of low back pain. The second involved physically active males and females, aged 18–23 years. Both studies included an experimental group that participated in ideokinetic imagery, an experimental group that did abdominal strength exercises, and flexibility work for the low back and for the hip flexors, and a control group. The second experiment also had a relaxation group, to determine whether ideokinesis or simply relaxation was causing the beneficial effects. In both studies, pre- and post-testing measured changes in sagittal curvatures of kyphosis and lordosis. Both experiments resulted in significant differences in the ideokinetic imagery group only, for male subjects, who showed reduced lordotic curvature. In subjective interviews, the ideokinetic imagery group also reported long-term reduction of low back pain. This study suggests that improving alignment patterns should include a component of neural retraining, and that ideokinesis is an effective method of achieving this retraining.

It is a known procedure in dance training settings to do assessments of alignment by observing the subject in static stance from the side, often in front of a grid or using a plumb bob.[20,48] The assessment procedures differ in the exact location of the line of gravity, such as whether the line should fall anterior or posterior to the ear, or whether it should fall directly through or anterior to the lateral malleolus. In spite of these differences, generally the plumb line passes through or near the following bony landmarks: the mastoid process, the center of the shoulder joint, the greater trochanter, the center of the knee joint, and the lateral malleolus.

Researchers have also used this method of examining alignment in dancers. Kerr and colleagues[31] assessed postural alignment by developing a prototype and a rating system based on skeletal placement of five body areas in quiet stance, and then having dance experts rate the dancers standing in front of a grid. The five body areas targeted were: (1) head, neck, shoulders, and cervical spine; (2) rib cage and thoracic spine; (3) lumbar spine, pelvis, and hip joints; (4) knees, lower legs, ankles, and feet; and (5) relationship of the center of weight to the base of support. The rating system was developed using the assessment procedures outlined by Fitt[20] and Plastino[48] and descriptions of alignment in the literature.[18,30,34,56,60,62]

What all of these perspectives share is a basic understanding that (1) alignment can be measured or assessed by examining the placement of bony landmarks during quiet stance, and (2) the dancer whose posture comes closer to a vertically stacked line is "better," meaning more efficient, less injury-prone, and more aesthetically pleasing. While these two ideas are fundamentally still prevalent in much of the current dance training, there is still the question as to whether this can be achieved through conscious, volitional muscular effort, or whether it is primarily attained through unconscious neural activation. For example, one method of correcting posture with anterior pelvic tilt and lumbar lordosis (swayback) and ribs forward is to use conscious muscular effort such as engaging the abdominals to bring the pelvis back to neutral, and pulling the rib cage toward the pelvis. Another method is to visualize a line of energy that starts at the center of the body and goes simultaneously down into the earth and upward past the top of the head, and imagine this line of energy elongating the body in the vertical axis. Changes to alignment using this method would occur due to altered neural recruitment patterns on an unconscious level. Hypothetically, it would seem that changes made in quiet stance through conscious muscular effort would have less success in transferring to locomotor conditions than changes made at the unconscious level of neuromuscular patterning. This hypothesis has been at the core of the theories known as the body therapies, or somatic practices.[1,2,19,56,57]

DYNAMIC ALIGNMENT AS ONGOING NEUROMUSCULAR RESPONSES

The Somatic Practices

In the early 1920s, Todd challenged the accepted notions of how to improve posture. Her philosophy was to use visualization, rather than to direct muscles voluntarily to change posture. In her 1931 article "Our Strains and Tensions" in *Progressive Education Magazine*, Todd called her approach the "opposite of fixity" (as cited by Matt[41]), and suggested that awareness and mental processes could alter alignment by affecting unconscious neuromuscular activity. In her view, establishing new alignment patterns requires two facilities: (1) the facility to form adequate mental concepts for stimulating activity in deep-lying muscles, and (2) the kinesthetic sense that gives rise to the perception of movement, position, and strain.[57]

Sweigard[56] developed her early definitions of good alignment from the work of Sir Arthur Keith,[30] who delineated traditional standards related to the placement of various parts of the body. Following in the ideology and writings of Keith and Todd, Sweigard was fully aware of the neuromuscular component of alignment as well. Her system, Ideokinesis, used imagery and kinesthetic awareness to affect the relationship and alignment of skeletal parts, by changing habitual neuromuscular patterns. These changes should not, in her view, be complicated by any voluntary holding or positioning of body parts. Matt[41] discusses Sweigard's work, stating that voluntary holding patterns succeed only in producing momentary improvement. Lasting change is more likely to occur with kinesthetic re-education, designed to improve underlying, unconscious neuromuscular habits. In Sweigard's 1929–1931 study of the results of Ideokinesis,[56] she used a measurement device called the Posturimeter, a large box with rods at various levels to determine vertical and horizontal positions of various skeletal parts. The subjects did 15 weekly Ideokinesis sessions, and multiple measurements were taken using the Posturimeter. Although there was no control group in her study, Sweigard observed positive changes in many segmental relationships.

Bell[4] describes the Alexander technique as psychophysical education that enables a person to become aware of tensions in the body. She defines inhibition as a function of the nervous system that eliminates unwanted activity. Inhibition occurs at the unconscious or reflex level and helps coordinate movement. In this view, the unconscious postural mechanisms underlie the focal, or volitional actions. Similarly, Lessinger[37] is a Feldenkrais practitioner who states, "Improvement of alignment is best achieved through the kinesthetic sense rather than through visual assessment and mechanical forcing of corrections" (p. 329). The somatic practices share this emphasis on awareness as the process, and on altering unconscious neuromuscular patterns to improve both static and dynamic alignment as the goal.

Although there is extensive anecdotal and experiential evidence of the value of the somatic practices in altering alignment at the unconscious neuromuscular level, there are few controlled dance studies that have been conducted in this area, and the results are mixed.[18,23,33,49,55,56] However, the research in motor learning and motor control may lend evidence supporting the theories and practices of these long respected somatic practitioners and dance educators. The motor control literature shares the view that posture is a dynamic process of ongoing neuromuscular adaptations on an unconscious level of recruitment.

Early Studies in Motor Learning and Motor Control

In the field of motor control and motor learning, there have been numerous controlled studies examining postural reflexes, that is, the unconscious neuromuscular patterns that underlie or accompany voluntary action, dating back to the 1960s and continuing to more current research.[3,6,7,10,13,14,16,17,21,35,39,40,45,63]

In the motor control literature, posture is described as the control of the body's position in space in relation to two aspects: (1) *stability*, which is the ability to control the center of weight relative to the base of support, and (2) *orientation*, which is the ability to control the relationship of body parts to each other and to the environment. Studies examining unconscious muscle responses to loss of balance used a device called the perturbation platform, which could shift forward or backward, or tilt upward or downward.[45] Subjects were not warned as to when the platform would move or what kind of perturbation would occur, and thus, they could not anticipate the timing or the nature of the perturbation. Two types of reactions to loss of balance were already understood prior to these studies. One is called the stretch reflex (or more formally, the myotatic reflex) and refers to the rapid contraction of a muscle in response to quick or extreme stretch. Onset latencies measure the time between the onset of the disturbance to balance, and the onset of the reacting muscles. The onset latencies for stretch reflex are less than 50 milliseconds. For example, when the ankle is suddenly twisted stepping off a curb, certain stretch-sensitive neurons in the stretched ankle muscles send signals that loop from the ankle muscles to the spinal cord, directly onto neurons that tell that stretched muscle to contract to protect itself. Because this sequence does not have to involve pathways all the way to the brain and back, the response time is extremely rapid. It is called a "short-loop" response.

A second response to loss of balance is volitional choice or reaction, in situations where there is time to evaluate the problem and respond accordingly. These response times are slow, relative to stretch reflex, and are called "long-loop" responses. The perturbation platform studies demonstrated a third response to disturbances to balance. Key points are: (1) Both the timing and the sequencing of muscle activation in response to the unexpected perturbations were highly constant across normal subjects and multiple trials. (2) The timing of onset latencies of muscle activation was too rapid to be long-loop or volitional response to loss of balance, but was too slow to be short-loop or stretch reflex response. Hence, a third motor program or neuromuscular synergy not previously defined was discovered. These responses were termed *automatic postural synergies* or *unconscious postural reflexes.*

For example, when the perturbation platform moved forward, the body would begin to fall backward. The automatic muscle activation sequence to this perturbation was tibialis anterior, followed by quadriceps, followed by abdominals.[45] When the perturbation platform moved backward, the body would begin to fall forward, and the unconscious muscle activation sequence was gastrocnemius, followed by hamstrings, followed by trunk extensors. The activation in these cases was distal to proximal (starting at the ankle and moving upward to the trunk), and thus, this strategy was named the ankle strategy. Because these responses occur after the disturbance, they are also referred to as reactive or compensatory responses.

In a later study, Horak and Nashner[26] found that when they altered the size of the support base, a proximal to distal activation was observed. The support base was a 2 × 4-inch piece of wood, and the subjects did not have their heels placed on the support. With the heels unable to support the weight, adjustment to balance moved up to the hip joint. Thus, this strategy was called the hip strategy. These studies suggest that the body can alter its strategy to accommodate various conditions. This potential for variation of a muscle synergy is referred to as plasticity. In other words, rather than being hard-wired, synergies show differing organizations in response to varying support surfaces and recent experiences.

Researchers have also been interested in what is occurring when the disturbance to balance was due to a planned action, rather than an unexpected perturbation. A study by Cordo and Nashner[13] involving pushing and pulling on a fixed handle demonstrated that there are proactive or anticipatory responses in the legs and trunk that occur prior to the planned, voluntary arm movements. These responses are similar to the reactive or compensatory responses observed on the perturbation platform. For example, with the push on the handle, which would cause the body to fall backward, the unconscious, anticipatory pattern shown was tibials → quadriceps → abdominals (distal to proximal), used to counter the anticipated force of the hand movement and its disturbances to stability. Once the hand was supported against anticipated perturbation to equilibrium, the volitional triceps brachii activated. With the pull on the handle, which would cause the body to fall forward, the unconscious, anticipatory pattern was gastrocnemius → hamstrings → trunk extensors, and then the volitional biceps brachii activated. It is interesting to note that when the task was repeated leaning on a chest support, no postural muscles in the lower limbs and trunk activated during the push or pull. Thus, studies suggest three key principles governing postural responses: (1) With prior knowledge of the event, postural responses will anticipate disturbances that can cause loss of balance, termed feedforward or anticipatory responses. (2) When surprises occur, such as the body's falling forward as the bus suddenly stops, feedback mechanisms elicit fast corrective measures, or compensatory responses. (3) When the body is supported by an outside stabilizing structure, normal postural responses that occur when the feet are the sole supports for stability are altered. Given the view in motor control research that posture is a dynamic process of ongoing neuromuscular adaptations on an unconscious level of recruitment, how do these unconscious responses coordinate with voluntary action?

Integration between Postural Responses and Voluntary Movement

Studies have indicated that the focal (voluntary) task and postural components of a voluntary movement need to be coordinated.[35] The term integrative control refers to the integration of unconscious postural mechanisms into ongoing voluntary movement, including locomotor mechanisms. For example, if a dancer were running across the stage, and suddenly slipped and lost balance, the postural reflexes to maintain balance would need to be integrated into the running pattern so that the dancer could continue locomoting across the stage. Frank and Earl[22] state "Postural adjustments that accompany movement serve to prevent or minimize the displacement of the center of gravity and thereby allow safe and efficient performance of movement" (p. 103). Hence, compensatory adjustments to unexpected perturbation occur during locomotion as well as during stance.

A study by Forssberg[21] demonstrated that anticipatory postural reflexes precede voluntary (or focal) movements during locomotion in a similar way to anticipatory responses in static stance. Subjects walking on a treadmill and pushing or pulling on a handle demonstrate postural responses in the legs that are superimposed on the locomotor activity. However, the type of anticipatory response is phase-dependent; that is, it varies with each leg depending on which phase of the walking action is occurring when the arm movement occurs.[46] Similarly, compensatory responses to unexpected perturbations are phase-dependent during locomotion. This demonstrates again the variability of the postural reflexes to conditions.

Additionally, it has been suggested that both postural and focal components of movement can be directed from higher centers in the brain, and they are probably organized in parallel and independent processes.[36] This means that it is not essential that the postural muscles be recruited prior to the voluntary movement. The muscles can be influenced by a variety of factors, and there may be some control exerted by the subject over the order of recruitment between the postural and focal activation. Lee et al.[36] found that in a study involving free arm movement (no fixed handle to push or pull), the recruitment order of postural and focal muscles was affected by temporal aspects. When the movement was self-paced, the postural muscles were recruited prior to the arm muscles. However, for fast-paced movements triggered by a visual cue, the postural and focal muscles fired at the same time. This again supports the idea of variability in the postural mechanisms, and suggests that behavioral and mechanical factors can influence the strategies used to maintain balance during voluntary movement. This plasticity of the postural reflexes raises an important question: Can postural reflexes be learned or modified, and if so, how can training enhance these unconscious neuromuscular responses?

Postural Reflexes and Training

There are numerous studies in the motor control literature suggesting that trained subjects have different postural reflexes than untrained subjects.[8,9,15,39,43,44,47,53] However, it should be noted before examining these studies that while they compare trained and untrained subjects, they are not training studies. Thus, the question of "nature versus nurture" remains unanswered. Are these trained subjects different from the controls because of their specialized training, or does elite activity select for people with inherently superior neuromuscular response mechanisms? Future research could indicate how training might influence or affect automatic responses of the body, that is, how learning is achieved at this level of neural activity. At this point in time, there are no training studies clearly confirming that training is the primary reason for superior postural responses in highly skilled subjects. However, there are studies examining effects of training on the ability of older adults to balance.[27,28,64] In particular, standing balance training in elderly subjects resulted in significant reduction in body sway under certain conditions, reduced co-activation of antagonist muscles, and reduction of onset latencies of specific muscles during disturbances to balance. Further, effects transferred to other balance tests, and remained improved for at least one month after training. While these studies do not involve elite dancers or athletes, they are certainly encouraging. It is, therefore, of value to examine the literature and the studies comparing trained and untrained subjects, and to explore potential training effects in elite individuals.

Frank and Earl[22] state that postural and focal sets (programming for muscle synergies) lead to the selection of specific motor programs, and this occurs in various areas of the central nervous system, including the motor cortex, the brainstem motor regions, and the spinal cord. Feedback from the environment is provided by somatosensory neurons in the proprioceptive, visual, and vestibular systems, and this feedback is compared with the internal model to determine success of the task. The discrepancy between what is expected and what is actual is used to modify the central nervous system model. This last step or phase contributes to the learning of novel movement tasks.

Meglin and Woollacott[42] discuss the association of postural adjustments (called postural presets), and state that this is made at a high neural level, in the association cortex, the basal ganglia, and the neocerebellum, where movement preparation and initiation originate. However, the link between movement and posture occurs at a lower level, the medulla and spinal cord. It is suggested that neural modification underlying balance improvement occurs at this lower level of sensorimotor reflex loops.[15] The question still arises as to what types of training might enhance the temporal, scalar (amount of effort), and spatial connections between unconscious and voluntary mechanisms.

Chatfield and Barr[11] considered three principles of training: anticipatory attention, central muscular activation, and simultaneous synergistic organization. They hypothesize that training utilizing these three principles leads to temporal improvements within and between unconscious postural synergies and intentional voluntary (conscious) synergies. This view of training is consistent with the somatic and the motor control perspectives that posture is a dynamic process of ongoing neuromuscular adaptations on an unconscious level of recruitment.

Several studies in the literature compare the balance skills of trained athletes and untrained subjects. Generally these studies indicate superior postural responses by trained subjects, and the researchers suggest that postural reflexes can be adjusted to higher performance by training.[8,9,15,29,39,47] Trained subjects showed more stability in one-legged stance[8] and demonstrated anticipatory, as opposed to compensatory, responses to planned balance tasks.[39] Brandt and Paulus[9] questioned what kind of training might produce improved balance, and concluded that subjects should be introduced to increasingly unstable conditions in order to enhance balance skills.

Debu and colleagues[15] looked at several studies including elite dancers and athletes in wrestling, baseball, football, water skiing, gymnastics, and basketball. In each case, they found differences between trained and untrained subjects, with trained subjects showing superior balance skills. In a study involving dancers, Shick et al.[53] found cross-sectional differences between levels of dancers, with advanced dancers having superior balance skills to intermediate or beginning dancers.

It has further been suggested that trained subjects develop new postural synergies. Pedotti and colleagues[47] tested postural synergies during axial movements, specifically fast backward trunk movements, and compared gymnasts with untrained subjects. This movement is fairly familiar in the training of gymnasts, but uncommon for untrained subjects. The untrained had a synchronous response, that is, the focal trunk movements and the unconscious postural reflexes in the lower limbs occurred simultaneously. The gymnasts, on the other hand, had sequential responses, with anticipatory activity in the lower limbs occurring prior to the fast backward trunk movement. Even though they did not test for training effects, these researchers suggest that long-term learning of new postural strategies may be caused by training.

Mouchnino et al.[44] compared dancers with nondancers in the performance of a well-known dance movement task, dégagé à la seconde to 45 degrees from turned out first position. They defined two phases, the ballistic phase, in which the gesture leg initiates the dégagé, and the adjustment phase, in which the body is finding a new balance on the support leg. They observed the following four differences: (1) The dancers reached the final position (steady state) at the end of the ballistic phase, having a very short adjustment phase. Non-dancers had two distinct phases, including a long adjustment phase. (2) The dancers had feedforward control (anticipatory postural reflexes) to the dégagé; that is, the muscles of the supporting leg and trunk fired prior to the dégagé gesture, whereas the nondancers had compensatory responses. (3) The dancers minimized the center of gravity displacement to the support leg, whereas the nondancers showed a larger displacement of the center of gravity. (4) The subjects demonstrated two distinct movement strategies, called the inclination strategy (nondancers) and the translation strategy (dancers). In the inclination strategy, the hips and head tilted to accommodate the shift of weight, and in the translation strategy, the hips remained level and the entire structure shifted over to the new support. Like Pedotti et al.,[47] even without actual pre-/posttraining data, Mouchnino et al.[44] suggest that these differences may be the results of training.

Monasterio and colleagues[43] conducted a follow-up study comparing dancers and nondancers performing a similar dance movement task, développé à la seconde to 45 degrees from cou-de-pied devant. Results showed trends suggesting that the dancers had anticipatory postural responses, while the nondancers had compensatory responses. While trials included both fast-paced and self-paced trials, it was the fast-paced trials that demonstrated the anticipatory responses in the dancers. Further, they also differed in using the translation versus the inclination strategy. However, as with the preceding studies, they are all simply cross-sectional snapshots of group differences at one point in time as opposed to training data collected repeatedly on the same sample as they progress through training. Therefore, it is unknown at this time whether the differences are due to innate predisposition, or to the training.

Dance investigators have also been interested in examining other aspects of neuromotor mechanisms in trained versus untrained subjects, including skeletal alignment in dynamic situations, and neuromuscular patterns specific to high level dance skills. Ryman and Ranney [52] studied two variations of grand battement devant, parallel and turned out, and compared four elite ballet dancers. Using electromyography (EMG), they found that each dancer had a unique pattern of muscle activation, even though the subjects were matched in terms of training and body type, and they all visually achieved the same goal. Through biomechanical analysis, the authors also discovered that executing the movement at the barre is not the same as in the center of the room without a support structure. Without the support of the barre, the dancer needed to adjust the center of weight backward in space so that it was over the one supporting leg. At the barre, no adjustment was made. The authors suggest that training at the barre, while valuable for developing strength and various technical and artistic skills, does not yield an improvement in equilibrium support mechanisms.

A recent study by Wilmerding and colleagues[61] supports their conclusion. Nineteen professional ballet dancers (aged 18–45 years) executed développé devant at the barre and in the center. Using EMG analysis, it was discovered that the muscle activations of the gesture leg (the focal activity) were the same in the two situations. However, the muscle activations of the supporting leg (the postural activity) were different. Activity of the tibialis anterior and abductor hallicus muscles (unconscious, postural activation) was significantly greater in the center than at the barre, suggesting that using an external support mechanism is not the same as working unsupported to prepare the body for equilibrium challenges.

Chatfield and colleagues[12] found that even when nondancers were given intensive training in performance of a select voluntary movement strategy involving a well-rehearsed, whole-body action, the dancers were significantly better than the nondancer controls. Thus, the difference between the two groups was not simply a testing effect, in which the dancers were familiar with the task prior to the study, but the nondancers were not. This suggests that long-term training may produce different results than short-term training, although the differences might still be the result of the selection process in dancers advancing through the ranks.

Two recent studies[58,59] also provide evidence that dance training might cause changes to neuromuscular patterning. In doing EMG measurements on stance, demi plié and grand plié, these studies found that ballet and modern dancers showed differences in certain strategies, and furthermore, that there was high individual variability, both within and across subjects. However, Trepman et al.[58] also suggest that these results may relate to body structure differences, rather than training. Because there is a selection process in career paths in dance, there is no way to know, without a longitudinal training study with matched subjects, whether it is the training causing the differences, or the initial body types and neuromotor systems of genetically gifted dancers.

Recent dance researchers have examined posture as a dynamic process of ongoing neuromuscular adaptations on an unconscious level of recruitment. In a study conducted by Krasnow et al.,[33] the alignment of dancers was measured using light-reflective markers and a motion analysis system. The light-reflective markers were placed on the bony landmarks consistent with the plumb line view of static vertical alignment. Both static alignment and the return to vertical alignment following an off-center, dynamic torso movement were investigated. Following pretests, four groups were involved in training: imagery only, conditioning only, conditioning with imagery, and controls who received no training. While there were no significant differences between groups in static stance, one group, the conditioning with imagery group, was significantly better at achieving vertical skeletal alignment immediately following the torso movement. This study suggests that training might influence alignment in dynamic situations, even when static alignment has not been altered.

Gamboian et al.[23] also conducted alignment studies during dynamic movement, and performed repeated trials over several weeks. They found that alignment is not only variable by condition but also variable day to day. Further, lumbar lordosis and pelvic tilt were independent of each other in this study, and one could change, while the other did not. This variability across a variety of factors suggests that research on dancers and alignment needs to incorporate a methodology covering multiple testing sessions and multiple trials, as well as providing an in-depth look at individual strategies.

Finally, the recent text on spinal stabilization by Richardson and colleagues[51] examines cutting-edge research on the unconscious activation of the transversus abdominis in perturbations to balance. The studies cited in this text were conducted by research groups headed by Cresswell and Richardson in the 1990s. Until recently, it was extremely difficult to measure muscle activation in deep lying muscles, as surface electrodes are not useful in measuring their function. In the late 1980s, ultrasound-guided techniques for needle insertion were developed, making it feasible to monitor the activation of the transversus abdominis in a variety of conditions, including static and dynamic trials of spine flexion and extension. Unlike the other abdominal muscles (rectus abdominis, obliquus externus abdominis, and obliquus internus abdominis), the transversus abdominus is not a spine mover—that is, it does not contribute to flexion, extension, or rotation of the spine; rather, it is active in breathing and in stabilization. The transversus abdominis was active throughout the trials in both flexion and extension, indicating that this muscle acts independently of the other abdominal muscles, which do not participate during extension. They also noted that in normal subjects, the transversus abdominis consistently demonstrated anticipatory activity to disturbances to balance, such as movement of limbs or trunk loading with weight. However, subjects with chronic low back pain and/or injury did not have consistent transverse abdominal responses. The responses in these subjects were late, erratic, or nonexistent. The researchers suggest that these differences in impaired subjects are related to motor control, that is, recruitment of the transverse abdominal muscle, and are not an issue of muscular strength or endurance. These authors are currently working on methods of training to enhance transversus abdominis activity in subjects demonstrating chronic low back pain and/or injury, and these methods may be useful for dance training as well.

SUGGESTIONS FOR TRAINING ENHANCEMENT AND RESEARCH

Both the somatic literature and the motor control literature have suggested that posture is a dynamic process of ongoing neuromuscular adaptations on an unconscious level of recruitment, and that training can alter or modify these unconscious neuromotor patterns. While the studies comparing trained and untrained subjects cannot confirm that training improves postural reflexes and neuromotor responses, they certainly provide evidence that better dancers have different postural responses than beginners or nondancers. Therefore, suggestions for training that specifically address these issues can be made. These suggestions are applicable to both the training requisite for developing elite professional dancers and the training that improves an individual involved in dance who will not reach the top levels of performance.

Several ideas for enhancing dance training are suggested by the writings in somatic practices, dance, and motor control. First, both cognitive awareness and kinesthetic awareness may well be keys to improving the automatic neuromuscular patterns governing alignment and balancing skills. Dancers should be encouraged to understand how the body functions, and how this relates to personal anatomical possibilities and limitations. The somatic practices can provide an exceptional method for developing discerning perceptions of the body, and allowing exploration in a conducive atmosphere.

Second, movement experiences may be crucial to the development of alignment in dynamic contexts as well as to the improvement of postural reflexes. Working on static vertical alignment may provide an experience of neutral "home base," but correcting skeletal placement in stance, making conscious and voluntary changes in the stacking of body segments, does not necessarily provide for the best anticipatory responses to dynamic movement through space. Both situations might need attention. Images and processes that dancers can apply while moving may be useful to this type of learning. The issue that is central to this discussion is transfer. How can the dancer transfer what is learned and absorbed at an unconscious level during static alignment to dynamic situations, involving speed, direction change, and perturbations to balance? It is possible that heightened kinesthetic awareness and the use of imagery and visualization techniques may be keys to transfer of training, as suggested by somatic practitioners.

Third, it is crucial that dancers practice balancing and movement tasks in situations where they are not supported by external structures, such as sitting and lying on the floor and standing at the barre. While these training mechanisms provide valuable skills and lessons, they do not challenge the postural reflexes in the same way as center and traveling work. Again, the issue of transfer is crucial in the training setting. Skills learned at the barre or sitting and lying on a support surface may or may not be applicable to similar skills required in unsupported standing and locomotor movement.

Fourth, it is suggested that movement perturbing balance at fast pace provides challenges to the neuromotor system that may not be occurring in slower-paced experiences. A full range of tempos and dynamics might provide the best possible training for equilibrium responses, thereby employing the plasticity of the neuromuscular system. Contextual variety may be a key to neuromotor excellence. Dancers should be given progressively more unstable and challenging conditions to balance. In this way, the unconscious neuromuscular patterns can receive the greatest range of experiences to enhance new neuromotor strategies.

The studies in dance science and in motor control have raised as many questions for researchers as for educators. Training studies are needed to determine what can be modified on the neural level, in terms of improving both static vertical alignment and dynamic neuromuscular responses. Issues of transfer from static to dynamic alignment, and from one context to another, are not fully understood at this time. Does slow practice transfer to fast-paced movement? Does work at the barre or lying and sitting on the floor transfer to center standing work and traveling work? How can researchers effectively measure alignment in static and dynamic situations, and how variable is alignment across days, across conditions, and across subjects? If alignment is as individual as the existing research is suggesting, a shift from group design to single-subject design in research methodology may be necessary. Collapsing data to group means may be masking important individualized strategies that would reveal valuable information about both static and dynamic alignment strategies.

CONCLUSION

This article has attempted to review the literature regarding various approaches to alignment, and to present a view of alignment that is one of dynamic neuromuscular responses. This perspective incorporates the ideas concerning skeletal placement as well as those exploring the automatic postural reflexes, and their integration with voluntary, focal neuromuscular tasks. Future research will hopefully provide evidence of the interaction of skeletal placement, postural reflexes, and locomotion, as well as other neuromuscular issues, and the potential effects of training on the neuromotor system. In 1950, Wells wrote the first edition of *Kinesiology: The Scientific Basis of Human Motion*, and addressed the complex issue of posture. In the 9th edition of this text, Luttgens and Hamilton[38] stated:

> By this time the reader should understand that posture influences all we do and that it is not a static but a dynamic configuration. It should also be understood that no single ideal postural model is appropriate for all individuals. Instead, there must be an understanding of the principles that govern efficient posture. These principles must then be applied to each individual (p. 453).

This statement is followed by a list of 13 principles that include the following as influencing or defining posture: the line of gravity and its relationship to the weight bearing segments, the relative extension of weight-bearing joints, energy expenditure, mechanical function of joints, use of muscle force (including the development of antigravity muscles and the balance between antagonist muscle groups), flexibility, coordination (including neuromuscular control and postural reflexes), kinesthetic awareness, organic function, personality, emotional states, age, and aesthetics. The final principle states, "In the last analysis, both the static and dynamic posture of any individual should be judged on the basis of how well it meets the demands made upon it throughout a lifetime" (p. 455). This broad definition of posture, encompassing the physical, neurological, emotional, and psychological aspects of the whole person, also raises the issue of lifelong endurance and function. Are researchers asking questions about alignment that concern only optimal performance during the short years of a dancer's career, or can the perspective include a concern for the years after the dancing has ended? Are educators teaching principles of alignment that satisfy a given aesthetic, regardless of its long-term impact on the body, or is the health and well-being of the dancer at the forefront of pedagogical developments? It is hoped that researchers and educators can begin to develop approaches to alignment that are flexible in relation to respecting individual differences, and inclusive of a variety of aspects of human function during one's entire life.

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ANNOUNCEMENT

Health and the Performing Artist

The British Performing Arts Medicine Trust will hold a conference on Health and the Performing Artist on August 21–23, 2001, at the Royal Scottish Academy of Music and Drama and the Theatre Royal, Glasgow, Scotland. *MPPA* Editor Alice G. Brandfonbrener, MD, is one of the keynote speakers. Some 200 delegates from the United States, the U.K., and Europe are expected. There will also be opportunities for less-well-known academics and practitioners to present their work in Short Presentation sessions as well as an area for Poster Presentations for the full duration of the conference.

The conference will take place in parallel with the world-famous Edinburgh Festival, providing delegates the opportunity to extend their stay to see some of the productions at the festival proper and the Edinburgh Fringe.

For a full draft of the program, registration details, or other information, please contact:

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