Revisiting Overuse Injuries in Dance in View of Motor Learning and Somatic Models of Distributed Practice

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Abstract

One hallmark of dance education is rigorous and repetitive physical practice. Of the many unifying theories of motor learning, the "power law of practice" states that repetitive practice of physical movements is a necessary ingredient in improving performance. Compelling evidence exists, however, showing that practice conditions where rest intervals are interspersed between movement repetitions ("distributed practice") play a strategic role in the acquisition and consolidation of learning motor skills. Further, repetition without adequate rest is implicated in overuse syndrome and has injurious consequences in both the peripheral and central nervous system. This article summarizes the research from neuroscience and motor learning on distributed practice conditions within the context of overuse injuries in dance. The neural consequences of repetitive movement without rest (adequate rest-to-activity ratios) are discussed. Schedules designed to promote motor skill learning and avoid overuse (adopted in somatic education, sports, and martial arts) are reviewed in the light of the current philosophy underlying dance practice schedules. Finally, the paper points to need for future research in designing protocols with higher rest-to-activity ratios in dance classes.

Rest can be defined as the "cessation of work, exertion, or activity."[1] In the western world, where a strong work ethic predominates, the benefits of rest have been submerged under socioeconomic and cultural notions that dictate that doing nothing is being non-productive, and therefore, "lazy."[2] For dancers, rest is a virtual oxymoron. The contemporary culture of dance emphasizes the "motor" end of the sensorimotor continuum,[3] where building a professional identity is accomplished by testing physical limits through extreme effort and exhaustive practice. To convey meaningful and nuanced beauty through an expanded movement range, dancers must spend supra-normal numbers of hours practicing in class and rehearsal, with additional hours devoted to personal physical cultivation. This article reviews the research from neuroscience and motor learning on repetitive practice in light of overuse injuries in dance. A dearth of evidence exists substantiating the value of any one practice condition in promoting motor learning or preventing overuse, and further research certainly is warranted. What research there is, however, points to benefits of expanded rest-to-activity ratios in motor learning. This research will be highlighted with a view towards reevaluating the role of somatic education in dance.

Motor learning theorists subscribe to the "power law of practice," which suggests that skilled performance evolves solely by the number of task repetitions.[4] Nevertheless, there is compelling evidence that the passage of time is also an important factor in the acquisition of motor skills.[4,5] Both the parsing or spacing of motor skill practice with rest embedded within the practice session or time periods that transpire after practice, appear important in the acquisition of procedural memory (the permanent learning and retention of motor skills),[5] and in avoiding overuse.[6] Mounting evidence from sports psychology, motor learning, and neuroscience supports the value of spaced practice conditions (balanced "activity-to-rest ratio") in a variety of motor learning contexts.

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Allowing rest intervals between repetitions has become an important concept in advancing the acquisition and retention of motor skills.[7]

Two types of practice conditions predominate in motor skill learning: "Distributed practice" and "mass practice."[7] Motor skill practice is called "distributed" when "the amount of rest between trials is equal to or greater than the amount of work within the trial"[7]). "Mass practice" is defined as "periods of work that are substantially longer than the amount of rest between trials."[7] Distributed practice is well researched in sports and other forms of cognitive skills. Several meta-analyses of sports and cognitive skill acquisition protocols have shown a small, but significant advantage, of distributed practice over mass practice.[8,9] Many factors would affect these reported outcomes, obviously, such as type of population (brain-injured vs. "healthy"), type of physical activity, muscles used, level of cognitive engagement, etc. Distributed practice, for example, has been shown to increase power and endurance in weight lifters,[10,11] whereas, mass practice has been shown to be a powerful agent of change in persons recovering from upper extremity hemiplegia after stroke.[12] Far more controlled research is warranted to substantiate the benefits of one type of practice over another, but at least the dialogue on rest within and around practice of motor skills is brought forward.

Practice Conditions in Dance

Where does dance derive its concepts for practice conditions? Dancers, whose expansive use of their bodies justifies their profession, appear to accept physical suffering as evidence of their dedication.[13,14] Dancers are expected to continually refresh their psychomotor energy stores to endure multiple repetitions or absorb novel movement combinations. Even when given a rest in the context of a dance class, dancers must keep high levels of cortical attention to attend to the next step or sequence to be learned in the phrase. Often, pre-professional dancers have less than 15 minutes to change classes, or less than 30 minutes to eat lunch or dinner before rehearsals. Despite good efforts being put forward toward building training programs embracing "holistic" approaches to dance injury prevention and wellness,[15] no actual protocols have been established for any type of dance style or training. The concept of intermittent rest intervals between movement repetitions remarkably is absent in published dance pedagogy, with the rare exception of personal biography, where authors give testimonies on the value of rest and other recuperative strategies.[16] Such a dearth of evidence in dance science exists that a recent textbook based on applying motor learning concepts to dance training does not even address the issue of practice conditions due to lack of research supporting any training protocols.[17] Search engines yielded scant studies on practice conditions in dance and their bearing either on motor learning or on wellness.

On the contrary, "tapered practice" and intervallic training are well-defined in the sports world.[18-20] Tapered practice allegedly promotes efficiency in motor performance by prescribing the most optimal duration, rate of reduction of training load, the form of reduction (whether step, linear, or exponential), and the balance between volume and intensity of work.[18] Tapered practice primarily addresses large time intervals. Research is far from exhaustive, however, on smaller time intervals, and specific protocols have yet to be standardized for any sport or activity, however.[20] Most protocols for intervallic training, for example, describe resting periods (of mixed duration) between exercise *sets*, rather than between repetitions (of any one movement). An exception to such studies is Lawton, and colleagues[10] who examined intervals of rest between repetitions of power lifting, not just after sets. Preliminary findings showed greater increases in power and endurance when rest intervals were interspersed between each lifting repetition as opposed to just after each set.[10]

In a review of the literature, only one article on dance training emerged relating the intensity and duration of training to rate of injury. Shan examined training conditions between elite ballet dancers and Tae Kwon Do martial artists, comparing their training regimens to the rate of hamstring injuries.[21] The researchers compared the Tae Kwon Do "axe kick" to the grand jeté in ballet, both of which require a series of steps to enter into the kick (preparatory phase) followed by an explosive, ballistic quick, full stretch of the hamstrings (kicking phase). Even though the intensity of training sessions among martial artists was greater (20% more hamstring lengthening per kick) and sessions were longer, hamstring injuries were 10% lower for this group than among ballet dancers. Shan theorized that shorter training sessions could account in part for the results.[21]

Augmented Rest: An Organizational Tool in Somatic Education

Martial arts share common pedagogical threads with somatic education ("somatics") in their emphasis on mind-body unity in training. Dance, too, shares common ground with somatics. A primary difference between somatics and dance, however, lies in the philosophical and pedagogical emphasis on restful reflection in learning to move. The role of somatics in dance education largely has been limited to "release" of tension (relaxation) or therapeutic healing and injury prevention[22] (with little research supporting these claims). Somatics—with its emphasis on embedded rest within activity—has often been perceived as "soft" practice (and therefore, not legitimately worthy of being a "dance technique"). There has been a tendency to conflate somatic disciplines with conditioning practices (such as Yoga and Pilates) as a means of justifying their inclusion within a culture of rigor.[23]

On the contrary, somatic methods rely largely on augmented sensory processes (in stillness and movement).[3] In other words, more time is spent attending to slow, gentle, quiet movement or body scanning at rest, particularly in the early phases of motor learning. Various strategies may be employed for augmented sensory awareness during these initial phases, such as using guided visual- and kinesthetic imagery or exploiting movement feedback (observing the effect of reducing the amplitude of movement, that is, performing micromovements). The redistribution of movement efforts is designed to enhance perceptual refinement to facilitate a more psychophysical state of embodiment conducive to coordinated action.[23] The concept of *doing* nothing implies an *active* reduction of somatic effort. In resting, a student is encouraged to observe themselves with attention to residual sensations, and to maintain a general state of open awareness to novel, more vivid reorganization of their self-image—a new place from where to act. From within this reduced activation, a recalibration of self-organization occurs which allows for more freedom of choice when reactivating movement. The primacy of sensory awareness (sensing) and of *continuing refinement of sensations* over physical practice (doing) is not just for rest itself, but is the key *agent of change* in perturbing habitual movement behaviors, and promoting self-organization[24] (internal authority).[25] While controversy exists in science as to the effects of perceptual refinement of movement feedback on motor learning,[26] evidence in dance education testifies to the negative effects of mirror training where visually-dominant perception self-perception (over kinesthetic-) interferes with learning complex phrases (as well as fosters other maladaptive behaviors).[27,28]

Virtually every somatic practice has embedded within its methods a balance between activity and rest. All these disciplines acknowledge pedagogically the importance of rest as a window of perceptual refinement in promoting coordination (motor learning). Somatic approaches common to dance curricula include Sweigard's "Constructive Rest" (and all of Ideokinesis), F. M. Alexander's Lying-Down work, the high rest-to-activity ratio in Feldenkrais Awareness Through Movement (ATM), the phases of open awareness following phases of "charged" movement in Continuum, and in Body-Mind Centering, the periods of "yielding," both to gravity and to sensation. Neuroscience appears to support this augmented rest-to-activity ratio as strategic for motor skill learning.[4,29] Larger periods of rest (24 to 48 hours) appear essential for memory consolidation of motor skills between training sessions.[29-31] Motor skill performance is known to continue (and improve) for at least 24 hours following training, suggesting that a good night's sleep is the best ticket to improving motor performance.[29,31]

Overuse Injuries in Dance

Theories on the etiology of overuse injuries in dance merit revisiting in light of somatics and its pedagogical emphasis on perceptual refinement through rest. Overuse injuries are a well-known phenomenon in dance science.[32,33] While many references to rehabilitation exist, concomitant references on practice conditions that would prevent overuse are nearly absent. Predominant models for overuse injury in dance science include among causes biomechanical (anatomical variation in alignment and agonist-antagonist imbalance),[33] and physiological (disturbances of muscle metabolism[34] and poor nutrition[35]) factors. Current theory goes further, however, emphasizing neurological causes. From this perspective, overuse syndromes result from perceptual dysfunction secondary to alterations at the peripheral level that centralize to higher neural centers.[36,37] Repetition without rest appears more implicated in overuse syndromes than either the amount of force or type of force (muscular contraction) generated. We are beginning to understand the perceptual consequences of repetitive movement and the need for an augmented rest-to-activity ratio to offset repetitive practice, even at low force skilled muscular activity,[6,37,38] Repetitive tasks with as little as 5% of maximal voluntary contraction can impair blood flow to the forearm, causing intramuscular ischemia.[39] Such submaximal isometric contractions also may play a greater role in the central component of fatigue than that induced by prolonged maximal effort.[37,39]

Centralization of the Problem

Alterations not only in muscle chemistry, but also in sensitivity of the muscle spindle (the muscle's sensory organ), have important consequences beyond the peripheral level. Convergence of nocioceptive inputs from muscles joints and skin on segmental interneurons lead to inhibition of painful agonists and excitation of antagonists, limiting use of the painful muscle.[38] Moreover, increased activity (hyperactivity) in the muscle spindles leads to attenuation of sensory input to the central nervous system.[6,38] Hyperactivity of muscle spindles (along with altered muscle chemistry) results in *perceptual* consequences which impairs the ability to discriminate intramuscular tension in the affected muscles.[39-41] In neurophysiological studies using sensory evoked potentials, for example, altered perception (decreased sensitivity to sensory signals) has been observed in persons with low back pain. Increased spindle input from the area of muscle spasm led to diminished responsiveness to stimulation of 1a spindle afferents.[6] Researchers speculate that changes in intramuscular sensation lead to decreased sensitivity and may lead to an inability to discriminate intramuscular sensation; this finding, particularly in the case of low back pain,[38] suggests that persons experiencing low level pain may be totally unaware that an overuse syndrome is developing.[6,38,40-42] The ability to discriminate intramuscular sensation, therefore, could be an important early indicator of marginal ischemia to working muscle due to overuse. Compound these risk factors with the "drive to continue" (keep repeating) the task, and the peripheral problem of overuse syndrome becomes compounded and centralized.[43]

Overuse…the Strain Lies Mainly in the Brain

Centralization of an overuse problem has potentially severe consequences for the brain. The peripheral problem of localized hyperactivity of the muscle spindle induces rapid modulation in the primary sensory cortex.[42,44,45] If neuroscience research is convinced of one thing, it is that the brain constantly is "learning" and is therefore, "plastic," changing dynamically with experience (including injury).[46] Sensorimotor regions of the brain contain multiple neuron pools, or "maps," whose neural fields (representational areas of branching synaptic connections) are extremely sensitive to afferent (sensory) input—the amount, frequency, duration, and intensity of input. These maps are highly discrete with clear boundaries, yet are constantly being reconstructed moment-by-moment within these boundaries with learning.[46] Physical practice can result in three options for changes in these maps: 1. the brain areas involved in the task performance can either increase (in size and density of neuronal connections), 2. these areas can decrease, or 3. functional reorganization of the brain can occur with changes across a number of brain areas.[47] Such changes are rapid, expanding with short-term bouts of activity (refinement of skill)[48] or shrinking with rest (e.g., vacations) [49] reviving the old adage "if you don't use it, you lose it."

One, however, might add to this adage: "if you don't use it *well*, you lose it faster." Byl and colleagues[50] presented an "aberrant learning hypothesis for repetitive strain injury," in which repetitive motion results not only in a peripheral injury, but more importantly, the "strain" lies mainly in the brain.[50,51] Rapid, alternating, repetitive finger and hand use (e.g., typing, tool-use) negatively alter brain maps. The primary somatosensory cortical fields representing cutaneous (area 3b) and kinesthetic (areas 3a and 1) inputs from the upper limb and the corresponding motor cortical undergo remodeling by repetitive the rapid-fire, repetitive input generated by the moving fingers. Formerly discretely mapped cortical regions can become degraded as neurons "bleed" into neighboring territories. Degraded representations, measured by changes in the size, distribution, and the overlap of the receptive fields, can occur in circumstances in which highly repetitive (several hours a day), spatially stereotyped (same patterns), and nearly synchronous input is experienced during activities requiring high cortical attention.[50] Such abnormal "penetration" of neurons into adjacent receptive fields confuses the brain. No longer, for example, can the brain clearly distinguish flexor and extensor surfaces of the fingers, leading to hand cramping. Hand cramping ("focal dystonia") prevents "fractionated" (individualized and independent) finger movements, regardless of the will to move otherwise, a well-known phenomenon feared by pianists. Even though further research is needed in understanding the benefits of distributed practice, the physical and neurological injuries from overuse and even the types off practice conditions that result in overuse are well-documented.[51,52] Re-learning how to move the hand becomes a long, arduous, and often unsuccessful process because one must retrain perception (normalized responses to sensory input).[50] Carefully controlled input conditions result in progressively more refined and more differentiated cortical representations of skin, muscle, joint afferents, and motor movements.[52] Extending these findings to the dance class is conjectural. So much of what is known in neuroscience about plasticity of learning has been done on the hand, since that is the easiest body part to study using neuroimaging techniques or electrophysiological recordings. Nevertheless, the results are compelling because of the hand's potentially complex motor sequences even in the simplest of tasks.

Ideokinesis: Motor Learning by Non-Doing

Of all the somatic methods, the one most historically and amply integrated into dance is Ideokinesis. A well-known legacy of literature (too long to list) exists from Mabel Todd's *Thinking Body* of teachers applying Ideokinesis ("imagined action") to dance movement. Further, of all the somatic methods, Ideokinesis is the approach most directly linked to motor learning (motor programming through mental practice and rehearsal),[53,54] and is the most studied in both "healthy"[54] as well as brain-injured populations.[55] More than six decades of research in sports psychology largely support the use of "mental rehearsal," that is, that motor learning is possible by simply thinking without concomitant physical effort.[53,56] The term "mental practice of motor imagery" has evolved to distinguish the mental imagery practice for motor programming as opposed to other kinds of imagination processes (e.g., auditory).[57] While integrated into a number of sports practices, mental practice protocols are far from standardized either for sports[56] or for dance.[58,59] One clinical study on subjects with stroke recommends a 10:1 ratio of visualization-to-activity (10 repetitions of visualizing dorsiflexion of the ankle joint) for motor learning.[60]

Neuroimaging (brain mapping) studies further confirm clinical studies that during mental practice of motor imagery, the brain uses the same substrates as in actual physical execution, alluding to the power of visualization in motor planning and programming.[61] Cortical excitation can be even higher with small forces than with larger ones,[62] and changes in cortical activity have been reported without signs of EMG activity, even when visualizing effortful movement.[63] At the bottom of all of these studies lies the question: Why physically use a body part to learn a movement when your brain can do it for you? A shift appears to have begun in dance training (at least at the university level) away from focusing on adapting sports science principles alone (inducing structural changes in the musculo-skeletal system) toward integrating somatic principles (whose pedagogy focuses more on the perceptuomotor aspects of skill learning). Select dance programs are viewing the integration of somatic education into dance curricula and tracking their effects, particularly in the area of rate of injury.[64,65] The dance community awaits more published research from researchers in these and other institutions.

Conclusion

The more we investigate motor learning, the more we realize that training is sensitive, specific, and requires all parts of the brain. Practice conditions play an essential role either in enhancing and consolidating positive learning processes or avoiding the onset of injurious motor behaviors. Preliminary findings from the motor learning research are positive indicating that rest (of some interval) has a beneficial effect on learning complex motor sequences. In the area of practice conditions for dance education, the field is wide open for research of rest-to-activity protocols. Dance researchers can approach researching the subject from a variety of avenues. Looking at the rate of injury over a season of dance training when rest is embedded (versus a control group where it is not), is one possible approach. For dancers, embedding rest into the dance class would provide fodder for research while contributing to wellness overall.

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