General Considerations for Guiding Dance Injury Rehabilitation

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Effective rehabilitation of dance injuries requires a skilled therapist capable of understanding the multiple factors involved in the injury's etiology and able to create a style-specific, staged rehabilitation plan, and a dancer ultimately committed to independent management of the injury, including an attempt to understand its cause. Dance rehabilitation is a dynamic process that ultimately depends on careful communication between the dancer and therapist. Fundamental to this process is the regular reassessment of the dancer's functional ability. In order for rehabilitation to be fully complete, the clinician-in-charge must possess a trained eye sensitive to the full palette of demands and nuances of the movement form to which the dancer wishes to return. Partnership with the injured dancer's teacher or artistic director is advised, and perhaps essential; the clinician should understand the dancer's work setting so that full movement skill refinement can be attained and the dancer become ready to seamlessly and confidently reenter her work setting.

Work Hardening

Dance-specific rehabilitation is well served when governed by the ergonomic principle of "work hardening." The American Physical Therapy Association (APTA) defines work hardening as: "a highly structured program encompassing not only physical rehabilitation, but also vocational and psychological preparedness to return to work."[1] Work hardening models depend not only on broad-based reconditioning, but also on practice of career-specific tasks in simulated work situations. The APTA's guidelines for work hardening include, "techniques to develop strength, endurance, movement, flexibility, motor control and cardiopulmonary capacity related to the performance of the work tasks; practice, modification and instruction in simulated or real work activities; education related to safe job performance and injury prevention including nutrition and weight control."[1] Within the work hardening model, dancers are viewed as individuals with unique characteristics that affect their ability to return to work, such as their ability to relate to the particular conditions in the workplace and cope with the organizational process associated with their occupation.

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Injuries

Injuries are common in dance. Between 50% and 80% of dancers report overuse syndromes sometime in their professional career,[2] and up to 46% of amenorrheic dancers experience stress fractures.[3] Sixty-five percent of all injuries in dance result from overuse, and the other 35% from trauma.[4,5]

Given that the ultimate goal of dance rehabilitation is to return the injured dancer to the work setting with full, pain-free function and better armed to prevent future injuries, it is important to first understand the following:

1. What constitutes a dance injury,
2. What injuries are commonplace among dancers, and
3. What is known about the etiology of those injuries.

What Constitutes a Dance Injury?

Dance injuries might best be defined as pain or physical dysfunction leading to missed participation in class, rehearsal, or performance. Thus, in rehabilitation, clinical decisions must be made based on the functional capacity of that dancer relative to the demands of his or her particular dance form and the demands of their role within that form.

What Injuries Are Commonplace in Dance?

Overall, across all styles of dance, injuries of the lower extremities are by far the most common. Table 1 illustrates the common injuries in various forms of dance at various levels of participation. The American Orthopaedic Society for Sports Medicine considers injuries as "sport-specific," because they tend to emerge in patterns representative of the motions and overall demands peculiar to each sport.[6] This concept holds true within dance as well. Typical injuries differ in different forms of dance; for example, in the studies shown in Table 1 it can be seen that ballet dancers report injuries to the foot and ankle more often than modern dancers. Modern dancers, by contrast, report injuries to their knees and backs more frequently than do ballet dancers. Injury patterns specific to gender roles within dance have also been noted. Data from injury reports collected over a nine year period from dancers in the Joffrey Ballet showed a 35% higher incidence of injury in the foot and ankle region in the female dancers compared to the male dancers.[4] Men, on the other hand, had a higher incidence of back pain than the women over the same time interval. Another study showed females in the Boston Ballet had twice the number of foot and ankle injuries compared to males in the company over a one year period, during which time the males had injuries predominantly at the knee, hip/thigh, thoracic spine/neck, and shoulder regions.[5]

In order to better understand why these patterns emerge and which rehabilitative principles and methods will best restore movement and full function, the common conditions associated with the occurrence of dance injuries must be understood.

Table 1[7] Common Injuries in Dance

Author	Level and Style	Number of Injuries	Injury Site Distribution
Quirk 1984[120]	Mixed level, ballet	(2113)	22.3% ankle 20.1% foot 17.3% knee 11.4% "other areas" 8.6% hip 8.5% lower back 7.5% lower leg
Liederbach 1985[121]	Professional, ballet	(256)	48.8% foot and ankle 18.4% leg 14.5% low back 7.4% knee 7.0% hip 3.9% neck, upper back, UE
Solomon 1986[122]	Professional, modern	(229)	20.1% knee 19.6% ankle 15.3% low back 14.5% upper back, neck,UE 11.3% hip 7.0% lower leg 7.0% foot
Garrick 1993[123]	Professional, ballet	(309)	37.2% foot and ankle 23.0% low back 6.8% knee

*UE = upper extremity.

What is Known about the Etiology of Common Dance Injuries?

Dance training is dictated by artistic traditions, not scientific principles. As such, traditional dance training does not universally incorporate modern conditioning methodologies that might better prepare dancers for the metabolic and tissue-specific stresses and strains they encounter during rehearsal and performance.[7] Although the purpose of dance differs from that of sport, dancers are athletes as much as they are artists, and the physical demands they endure are potentially as stressful as those faced by other athletes. Well-informed training supervision may reduce occupational injuries and illnesses. The known factors associated with the etiology of common dance injuries can be condensed into three broad categories: occupational demands, movement demands, and training oversights.

Occupational Demands of Dance

Dancers, like other athletes, are subjected to circumstances that require above average strength, flexibility, coordination, and concentration. Further, they are often subjected to rigorous aesthetic demands, such as the maintenance of thinness and the need for exquisite motor control at end-range postures on precarious bases of support. On top of these occupational demands, there is little professional or financial security available to those pursuing a career in dance, often making access to health care services difficult. These conditions plus the fact that dance, unlike sports, knows no regular seasons, place a tremendous toll on the performer.

Selection of Dancers

Dancers are typically selected for artistically pleasing qualities manifested, in part, by certain physical and psychological tendencies. Unfortunately, many of these tendencies are also associated with increased risks for injury. Some of those tendencies profiled in dancers are identified below.

Physical Tendencies

Looseness

Dancers tend to be hypermobile and selectively hyperflexible.[8-13] While these are aesthetic assets in that they permit the accomplishment of the extreme ranges of motion needed in many styles of dance, these attributes may enhance the risks for injury. Chronically overstretched muscles and tendons show decrements in muscle spindle output

and reflex force characteristics.[14-16] In addition, hypermobile dancers perform poorly on tests of propriception,[10] suggesting that changes in neural elements accompany the changes in tissue length, which may adversely affect motor skills.[17] Anterior cruciate ligament injuries, for example, have been linked to altered muscle recruitment patterns associated with a long amortization phase in the stretch reflex response.[18-19]

Tightness and Weakness

Screening data from tests performed at the Harkness Center for Dance Injuries on 800 healthy, non-injured, adult advanced (college or professional) dancers from various dance forms revealed that 76% tested positive for calf tightness and 63% tested positive on Thomas tests for hip flexor tightness. In that same population of dancers, 68% failed tests for normal muscular endurance of the plantar flexors; 50% failed tests for functional quadriceps control (maintenance of lower extremity alignment during bench stepping), and 38% failed supine double leg lowering tests for abdominal strength/trunk stability. Past studies corroborate the finding that dancers lack strength in certain muscle groups.[8,20-23] Dance is an intense, highly repetitive, high impact activity. Muscular strength and endurance are important in joint and postural stability, shock absorption, motor control, and performance stamina. Relative imbalances and deficits in strength pose significant risks for injury.

Thinness and Low Energy Expenditure

In the sports medicine literature, dance is considered a "thinness sport"[24] and women ballet and modern dancers tend to be on average only 75% and 88% of expected body weight, respectively.[27-28] Problematically, dance is not a calorically expensive movement activity.[25,26] Yet, most dancers report doing no other form of adjunctive aerobic exercise to improve fitness or weight control. Because of this, chronic dieting to restrict calorie consumption as a strategy for maintaining low body weight is commonplace among dancers.[27-34] Inadequate energy intake and nutritional imbalance are factors known to increase injury and illness risk. The actual risk for injuries associated with The Female Athletic Triad Syndrome[24,35,36] (the relationship between amenorrhea, disordered eating, and osteoporosis) is difficult to quantify,[35] but clinicians should be aware that amenorrhea has been linked to decreased estrogen, a condition which is linked to the pathogenesis of osteoporosis.[29]

Psychological Tendencies

Personality

Personality traits associated with the drive necessary to achieve elite levels of physical skill in ballet have also been associated with occurrence of injuries. Ballet dancers with the greatest number of total injuries throughout their careers, regardless of gender, were found to be significantly more enterprising than those with fewer injuries, and ballet dancers with stress fractures and other overuse injuries were those with the personality type of overachiever.[2]

The Dancer's Cultural Context

Success in rehabilitation involves empathy on the part of the clinician for the psychological culture within which a professional dancer rises. As described by Kerr and associates, "a dancer is someone who trains daily for 10 years or more, investing time, money and energy with the foreknowledge that gainful employment is questionable, and that even success guarantees little, [...in fact, a] good chance of living at the poverty level. Dancers have different values and priorities from persons in mainstream career cultures."[37] In that same study, the authors reported that only 20% of injured dancers pursued a physician visit for care of their injuries, reasons being lack of money and time and that the dancers had a feeling that the physicians viewed their problems more incidental than they wished.

Movement Demands of Dance

Hamilton has noted that dancers, even if perfectly conditioned and trained and psychologically prepared for the rigors of a life in dance, will experience injuries, simply due to the nature of the movement demands.[7,38] Some of the movement demands in dance known to be linked with injury risks are reviewed below.

Posture and Alignment

Since femoral neck anteversion angles in dancers are similar to age-matched, non-dance trained individuals in the general population,[39] dancers must borrow movement from the spine, pelvis, and lower extremity segments to achieve turnout in stance.[8,40] It is not uncommon for dancers to friction-couple their feet with the floor to achieve full turnout, a behavior that may produce excessive forces along the kinetic chain and resultant plastic changes in tissue structures surrounding various joints.[41-44]

Base of Support

In dance, the feet do not always serve as the body's base of support. Many dance forms rely on the knees, buttocks, spine, neck, upper extremities, or head to serve as a transitory base of support, presenting a whole new class of injury risks.[7] Dancers are sometimes asked to try one of these interesting postures without any special instructions, safety precautions, pre-conditioning exercises, or warm-up activity and then often repeat the maneuver over and over again.

Balance and Proprioception

During our screenings at the Harkness Center for Dance Injuries, we have found that it is not uncommon for dancers to have some residual balance or proprioceptive deficit or problem from a previous illness or injury. Forty percent of the dancers we test during preventative screens fail Romberg tests or demonstrate increased radial displacement and area per second of sway from center of pressure on force plate stance trials. These deficits place the dancer at increased risk for trauma because of the associated alterations in neuromuscular feedback.[45-48] Dancers rely on a keen sense of balance to sustain extremely small bases of support for extended pe-

riods of time as well as to move rapidly and expansively between spatial postures – often shifting direction, timing, and level multiple times within just one movement phrase. Balance is, of course, governed by postural control systems, including the vestibular apparatus, which provides information about body accelerations and orientation in an inertial frame of reference; the visual system, which provides information about the environment and about the orientation and movement of the body; and the proprioceptive system (the muscle, joint, and cutaneous receptors), which provides information about the state of the effector system and the environment.[49]

Movement Demands on the Spine, Pelvis and Hip

The majority of back injuries, like most other dance injuries, can be attributed to repetitive movement stress. In dance, repetitive microtraumas occur from asymmetrical loading of articular and soft tissue structures during end-range movements that level and unlevel the pelvis as the center of gravity is shifting.[50] Sacroiliac dysfunction is the most common lumbosacral pathology in professional, classical dancers and is a result of the forces inherent in the extreme movement demands and the ligamentous laxity possessed by most elite dancers.[51] Because of the technical demands placed on dancers to maintain a square torso, there is also increased demand for stability of the trunk against large movements of the lower limbs. This may result in functional hypermobility of the pelvis. Many dancers are able to assume extreme hip and lumbar spine hyperextensions, creating a great deal of spinal rotation in opposition to the stance limb. The attempt to accommodate these ranges of motion may lead to excessive vertebral rotation, hypermobility at the lumbosacral and sacroiliac (SI) joints, or sometimes, from spondylolysis. The incidence of spondylolysis and spondylolisthesis in dancers (12% to 17%) resembles that of elite gymnasts, and is higher than the general population (6%).[13,52]

Lower extremity weakness is considered both a cause and an effect of lumbar spine and pelvic injury.[53,54] Other injuries in this region linked to movement demands are muscular spasms and overuse syndromes. For example, dancers frequently complain of clicks, pops, and snaps around the hip, which are most often associated with passage of the tensor fascia lata tendon over the greater trochanter or of the iliopsoas tendon at the iliopectineal eminence.[41,55] Intra-articular causes of snapping hip symptoms include synovial chondromatosis, loose bodies, osteochondritis dissecans, osteocartilaginous exostosis, labral tear, or inverted labrum. The piriformis muscle can become short and tight, due to chronic turnout postures. By virtue of its muscular attachments, persistent piriformis spasm can limit pelvic and lumbar movement and lead to antalgic gait deviations.

Movement Demands on the Knee and Leg

The knee is exposed to considerable stress in dance. Dancers perform approximately 200 jumps per class,[56] usually with some transverse plane rotation for the lower limb provided by the tibiofemoral joint.[8] Patellofemoral syndromes are common in dance and thought to be related to the high frequency of eccentric loading secondary to the repetitive landings from jumps.[57-62] Improper mechanics on jump landings, such as double heel contact or no heel contact, has also been linked to shin pain.[63] Inefficient distribution of the forces throughout the foot and eccentric stretch velocities that are unable to assist the recoiling and elasticity of the lower extremity muscles have been cited as probable causes of pain.[64]

Movement Demands on the Ankle and Foot

Two of the regularly practiced ankle movement actions in dance – relevé and plié – are associated with a number of orthopaedic problems. During relevé en pointe, bone-on-bone forces at the ankle are estimated to be about ten times body weight, comparable to that of a runner doing a six-minute mile.[65] Forces acting across the great toe joint during relevé are equivalent to more than twice body weight.[65]

The position of relevé produces a loss in anatomic stability of the talocrural joint (relatively close-packed in stance). Without anatomic stability, surrounding musculature, most notably the peroneals, are forced to contract more forcefully to stabilize the foot.[66,67] Further, "winging," or relevé with eversion (a stylistic embellishment on the formal relevé position), markedly increases the pressure at the first metatarsophalangeal joint. Indeed, this foot posture also places the first ray in a mechanical disadvantage requiring the flexor hallucis longus and other supporting soft tissues to overcome inordinate tensile forces and encounter greater resistance to flexion of the digits.[68] If the flexor hallucis longus tendon (referred to as the "dancer's Achilles heel")[66] becomes inflamed, it may progress to partial rupture. Erosion of this tendon within its osseofibrous tunnel (known as stenosing tenosynovitis) can result in a condition commonly referred to as "trigger toe."[42,58,66,69,70]

Dancers spend a great deal of time in the hyper plantar flexed ankle and foot position of relevé. Because of this, they have been shown to develop a tight gastrocnemius-soleus complex with an accompanying loss of active dorsiflexion.[8,21,71] The pathomechanics of functional equinus include adaptation for dorsiflexion at the midtarsal region and, therefore, extended pronation into gait cycle phases, exposing the dancer to excessive pressure and tensile forces on the medial column of the foot and, in turn, leading to increased compression forces at the lateral cuboid.[72-73] Prolonged pronation allows for an unlocked forefoot near the toe-off phase of gait, where the angles of pull of the anterior tibialis and peroneal longus muscles are less optimal in their relationship to the first ray preventing the ray from assuming its most effective position as a stable and rigid lever for propulsion.[72]

By contrast, limitations in ankle plantar flexion or metatarsopha-

langeal (MTP) dorsiflexion, especially in relevé, can cause calcaneal inversion or "sickling" and may increase the risk of lateral ankle sprain. Lateral ankle sprains are often accompanied by "dancer's fracture," a spiral fracture of the shaft of the fifth metatarsal. They may also be accompanied by distal fibular fracture, interosseous membrane irritation, and/or subluxation or dislocation of the peroneal tendons.[58,74] Other foot fractures are also common in dance, specifically, in the second metatarsals,[67,73] the pedal sesamoids,[75] and the Lisfranc's joint.[76]

Related to the position of plié, male dancers have been shown to develop anterior ankle impingement problems more frequently than female dancers and its occurrence has been associated with years of high impact landing from large jumps into the demi-plié position where anterior articular margins of the tibia impinge on the talus and bone spurs develop. Anterior ankle impingement is associated with eccentric weakness of the calf and can lead to a decreased range of motion at the ankle and compensatory pronation or supination, depending on its location. This, in turn, can result in capsulitis of the first MTP joint.[60]

Two other common problems associated with foot and ankle injuries in dance are inadequate strength and ill-fitting or poorly designed shoes. Compared to soccer and football players, ballet dancers have significantly weaker dorsiflexors than other athletes, both alone, and in relation to plantar flexors and overall ankle strength.[77] Contrary to what one might expect, the pedal intrinsic muscles in female ballet dancers tend to be weak and may require some instruction in doming exercise. Pedal weakness may be due to the shoes they are required to wear in addition to the repetitive stress described above. Most dancers fit themselves for pointe shoes based on the visual appeal of a particular shoe, rather than for a truly proper fit. Very often the flex point of the shoe does not align with the first MTP joint, causing the dancer to place more compression stress and inordinate shear loads at this joint. The shoes may fit so tightly that they prevent the foot muscles and proprioceptors from being fully utilized because the foot is unable to articulate well in the shoe. Furthermore, most pointe shoes are made of inefficient shock absorbing materials (cardboard, satin, and leather) and unforgiving vamps so that impact loads are high.[7]

Training Oversights in the Traditional Dance Setting

Perhaps the most important category of etiologic factors associated with dance injuries is training oversights. Four of the major principles of kinesiological science[78] are neglected or poorly incorporated into dance settings. Because they are so important to the prevention of dance injury, each will be addressed separately. These principles are:

1. Periodization,
2. Specificity,
3. Overload training, and
4. Over-training.

The Principle of Periodization

The principle of periodization is concerned with the timing and intensity of training exposures. This principle asserts that sufficient time must be allowed between workouts for tissue growth, nutritional replenishment, and biochemical resynthesis to occur while exposures to work overloads are gradually increased in order that optimal physiological development and fitness be achieved.[78] One problem inherent in traditional dance settings is that regulated periodization to training and performance exposures is lacking. Typically, dance company schedules are not as seasonally predictable as organized sports schedules. Hence, adequate rest cycles and safe, step-up phasing of performance stress overloads are not reliably incorporated, placing the dancer at increased risk for repetitive stress and fatigue injuries.

The greatest number of injuries per year are reported during the end of the day and/or the end performance seasons when dancers became most vulnerable to fatigue[74,79,80] Fatigue has been demonstrated to have adverse effects on neuromuscular control and coordination, reflex activity, and muscular power.[14,81-83] Previous reports[84-86] have implicated muscle fatigue as the origin of tibial stress fractures, an injury common in ballet dancers.[87,88]

The Principle of Specificity

The principle of specificity refers to the phenomenon wherein a specific demand made on the body results in a specific response by the body.[78] The principle states that in order for a particular movement skill to be achieved, that skill must be trained by imposition of exactly similar motions, intensities, and durations to that of the goal movement.[89] For example, if a dancer wants to become proficient at a particular type of jump, he or she should practice that jump, in a constructive, progressive, and exacting manner, until the ultimate level is achieved.

Traditional dance settings typically lack specificity when it comes to crossover of movement vocabulary from the technique classroom to the choreographic application in the rehearsal and performance setting, as well as in terms of metabolic pathway trained in classroom versus that which is required during stage performance.[20,25,90-93] Motor patterns, muscular contraction demands, and cardiopulmonary demands vary between the classroom and stage[91,92,94]; classroom technique training remains relatively constant while the choreographic application is ever-evolving in its creative departure from baseline technique. An unspoken and ungrounded assumption that dancers are ready to handle these differences permeates most dance environments, again leaving the dancer vulnerable to otherwise avoidable injuries. For example, dance training in the classroom does not specifically pre-condition for the demands of lifting, and hence, the dancers who are required to execute the lifts are at risk for traumatic overload injuries. In three British ballet companies, one-third of all back injuries suffered by the men were attributed to the demands of lifting.[95]

The Principle of Overload Training

The overload principle states that, "beneficial human performance adaptations occur in response to demands

applied to the body at levels beyond a certain threshold value, but within the limits of tolerance and safety." The limits of tolerance and safety are often exceeded in dance, particularly when a student jumps from 3 to 5 classes per week during the school year to 3 to 5 classes per day in a summer-intensive program. Another example where the limits of tolerance and safety are violated would be similar to the situation described above under specificity, where the shift from classroom movement to studio/stage movement is progressed without proper overload step-up training for safe mechanical and physiological management of the performance stresses. If too great a stress is imposed over too short a time, the body will be unable to adapt and there will be a decrement in performance possibly resulting in injury.

Thought of from the opposite side of the same coin, the overload principle also asserts that "low-level demands, to which the body has already adapted, are not sufficient to induce a further training adaptation."[78] Once a dancer has reached an advanced level of technique, the demands of the classroom training remain relatively steady, failing to further advance fitness beyond the tasks of the classroom itself. While the repeated practice of technique during class work is very beneficial to both motor learning and motor control, it is inadequate training for the physiologic capacities of strength, power, and endurance required by the more demanding aspects of performance.

The Principle of Over-Training

The over-training principle states that an individual ceases to adapt positively to training stress when it is imposed in a sustained, long-term, and highly intense manner. Dancers are at risk for developing the overtraining syndrome (defined as an unexpected drop in performance that cannot be attributed to illness or injury) when they are required to execute frequent performances, undertake consistent training that is monotonous in nature and lacks sufficient rest periods, when they consume a poor diet, and when they are exposed regularly to psychosocial stressors including work or school conflicts (especially if they have poor coping abilities).[37,90,97-101]

Dance-Specific Rehabilitation

When one considers the etiologic factors associated with dance injuries, it is easier to see why style-specific, multi-factorial, staged rehabilitation programs are needed in order to fully restore function to a dancer and safely return him or her to pre-injury level of participation.

Rehabilitation must begin immediately after injury and end when the dancer returns to full activity without limitations imposed by the injury; has full confidence in the stylistic demands of movements, stage sets, partners, and costumes; and understands why the injury happened and how future injuries can be avoided.

Structuring a Work Hardening Rehabilitation Plan for Dancers

Throughout the rehabilitation process, the clinician must ask:

1. Which components of the overall demands of this specific form of dance are called for from this performer and are limited in this individual?
2. How can I determine this dancer's current highest level of function?
3. How should I progressively task load the patient in a logical, step-wise fashion in order to achieve maximum capacity in the safest and most efficient manner?

One of the most successful ways to frame answers to these questions is to obtain normative screening data on healthy dancers within a given dance form. When the range of capacities of injury-free, elite dancers of a particular form are known, the clinician is equipped with normative values to which individual patient measures can be compared at the time of injury and over the course of rehabilitation.

Rehabilitation must be progressive and should always begin simply, gradually accumulating length, difficulty, and planar as well as cognitive complexity. The principles of periodization, specificity, and overload must govern all dance rehabilitation protocols with the aim of "training the body by involving systematic uses of repetition and progressive loading to stress the musculoskeletal, respiratory, cardiovascular, and nervous systems so that the various components of physical fitness (including strength, flexibility, neuromuscular coordination and cardiovascular-respiratory function) are enhanced. As a result, the dancers will be able to perform movements repeatedly, efficiently, with optimal form, and without undue fatigue."[89]

Periodization

Appropriate rest between bouts of progressive strength and cardiovascular training are needed to properly prepare the dancer for their work demands and to offset the effects of fatigue. In the rehabilitation setting, clinicians should inquire about the injured dancer's schedule and provide guidelines about injury prevention as it relates to fatigue.

When facilitating the restoration of function in the clinic, it is important for the clinician to be aware of the effort put forth by the dancer in any restorative exercises, in addition to the overall effort exposure (what else has the dancer done that day, week, year as well as how many years of their life they have been training). Values such as perfectionism and daily personal-bests are engrained in the dancer. Relative rest and time-out from some activities in order to restore function progressively is anathema to their sense of professional responsibility as well as to the maintenance of their identity and self-worth, yet essential to their healing and career longevity.[7] It is the clinician's role to educate the dancer fully about the risks associated with insufficient rest.

Specificity

In order for a dancer to safely return to dance after being injured, stresses placed on him or her during rehabilitation must specifically address the demands that he or she will assume upon return

to pre-injury activities.[96] In the rehabilitation setting, it is incumbent upon the clinician to not only address the movement, muscular, and cardiopulmonary deficits the dancer is likely to possess, but also to educate the dancer about specificity and conditioning necessary to make them ready to meet the demands of performance.

Specificity also refers to conditions in the work environment that might have an impact on the dancer's performance, such as floor surface, costume construction, stage light levels, and set design features. Part of a thorough dance rehabilitation program is to fully appreciate the working conditions to which the patient is returning and to simulate similar conditions in the clinic so that the dancer can be fully prepared.

Overload Training

Too often, dancers mistakenly believe that they can "dance to get into shape," rather than understand that they need to "get into shape to dance." Overload training is essential for dancers, as is hopefully becoming evident. Overload during therapeutic exercise can be quantified in terms of training volume (amount of work done) and training intensity (rate of doing work).[78,89]

To achieve progressive strength training, volume can be manipulated through the number of repetitions performed, and intensity can be manipulated by amount of weight being lifted. To achieve progressive cardiovascular training, overload can be achieved by manipulating volume by increasing the length of time spent exercising, and intensity can be manipulated by requiring progressively increasing heart rate and perceived exertion levels.

Over-Training

Like with periodization, it is important that clinicians understand the global fatigue status of the dancer who is undergoing the process of rehabilitation. The dietary habits, general health status, and cumulative exposure to dance and other life stressors should be assessed so that training can progress safely, as there may be a mismatch between stress and capacity.

Successful rehabilitation is always modified to an individual's diagnosis, severity of injury, and functional expectations. Because of the differences between individuals in terms of pathologies, physical and psychological constitution, and workplace demands, there is no set timetable for each stage in a return-to-dance treatment progression. Styles and types of exercise are always determined on a case-by-case basis, depending on the dancer's pre-injury status, their stage of healing with regard to weight-bearing, and the form of dance performed.

Table 2 shows the four stages of progression that a work-hardening rehabilitation protocol takes dancers through. The progression shows both clinical goals and coinciding dance movement goals. The progression takes dancers from a restricted phase (wherein acute management of the injured tissue is the primary focus) to a refinement phase (wherein dance-specific motions in full weight bearing are practiced in ever increasing volumes and intensities).[7]

Addressing the Etiologic Factors during Dance Rehabilitation

Posture and Balance

To dance well and to dance safely, the dancer must be able to successfully weight shift his or her center of gravity over the base of support precisely and efficiently as well as grade movement speed. To safely control rotational forces around the body's vertical axis during turning activities, trunk strength is essential; it has been associated with postural stability and optimal weight transfer strategies and with adequate deceleration grading during turn skills in dancers.[102-104]

Balance and proprioception can and should be restored in the rehabilitation process. They can be re-educated by advancing rehabilitation activities from stable surfaces to unstable surfaces, as well as onto surfaces of

Table 2 4-Stage Rehabilitation Protocol[7]

Rehabilitation Stage	Clinical Goals	Studio Goals
Stage 1: Restricted Stage	Reduce swelling and pain Active rest Evaluate kinetic chain for dysfunction Aerobic conditioning	Restrict tissue loading Somatics and mental practice Take floor exercise class or pool class
Stage 2: Restoration Stage	Restore ROM and strength Progress aerobic conditioning Begin functional weightbearing and basic skills	Permit limited movement with restricted tissue loading (padding, taping, etc.) Concentrate on alignment and stability Take beginner level dance class
Stage 3: Reacquisition Stage	Progress strength to "supernormal" levels Bilateral → Unilateral weightbearing Eyes open → Eyes closed Slow → Fast movement exercise	Return to original level class Progress from 1 class/day to more, as tolerated Limit number of jumps and rehearsals
Stage 4: Refinement Stage	Build confidence, carriage, and control[187] Complicate skills Progress cardiovascular drills Increase speed and loads Progress dynamic balance Increase repetitions	Unrestricted dance movement Prescribed warm-up Implementation of injury management and prevention techniques learned in rehabilitation Understanding of nutritional needs discussed during rehabilitation

Table 3 Functional Progressions for Dance[7]

Parameter	Basic Level	Progressed Level
Movement Patterns	Pedestrian stance and gait	Ballet stances and skills
Cardiovascular	20-40 mins, four times per week, target heart rate	40 mins, four times per week, alternate aerobic with anaerobic bouts of ratio 2 minute max heart rate
Strength	Wide, "parallel" base proximal resistance keeping trunk in sagittal plane	Sagittally restricted "turned-out" base distal resistance; moving trunk, upper extremities, head and eye focus throughout frontal and transverse planes
Exercise Tempos	Slower	Faster
Mechanical Loads	Lighter	Heavier
Balance	Two legs Grounded base of support (e.g., plié)	Single leg Narrow base of support (e.g., relevé)
Surface	Stable floor	Trampoline, sand, mattress, moving treadmill
Vision	Eyes open Comfortable light level	Eyes closed Dim or very bright light level
Jumping	Low height, low repetitions Two feet	High height, moderate repetitions One foot
Concentration	Perform simple verbal recall while performing balance task on stable floor surface	Perform complex verbal recall while executing balance tasks on unstable surface. Reverse

varying texture, like sand pits, mattresses, beams, and trampolines. Balance and proprioception have been shown to improve through the practice of various postures on diminished bases of support, such as, for example, stance on a balance beam or water skis.[105] When dancers have become accomplished in these progressions, they may be asked to balance while having their task-oriented mental concentration distracted. This can be achieved by having them catch or throw a ball while balancing on challenging surfaces or bases of support, by having them recite what they had for dinner the night before, or by having them lift small dumbbells through a port de bras pattern while maintaining a strong center over their base. With regard to dynamic balance, recommendations for progression are to move from slow to fast speed, from low to high force activities, and from controlled to uncontrolled activities, which are acceleration and deceleration specific. Changing the light levels during any of these activities will further amplify the training effects as well as successfully simulate the dance performance environment.[106]

Flexibility, Strength and Cardiovascular Fitness

One of the most challenging aspects of rehabilitating a dancer is in striking a balance between stability and mobility, so that individual joints and kinetic chain links are protected while still allowing for virtuosic accomplishment by the dancer in his or her technical movement.

The role of muscle mass, muscular strength, and muscular power must not be underestimated by either the dancer or the clinician. Dancers should not be discharged from rehabilitation without a specific home exercise plan for ongoing and progressive strength training.

Unless there are special medical or psychological concerns, the clinician should introduce aerobic exercise into dance rehabilitation protocols as early as possible in order to increase energy expenditure and allow the dancer to maintain a lean body weight while improving nutritional intake. Additionally aerobic exercise enhances cardiovascular conditioning and thus offsets fatigue.

Movement

In rehabilitation, the clinician should judiciously restore normal joint motion and design exercise regimens that require the use of under-utilized movement ranges while resting overused tissues. Since dancers have to initiate strong muscle contractions from maximally stretched positions and execute isometrically controlled balances and multi-segmental shapes, strengthening and balance exercises that mimic these shapes are recommended, in keeping with the principle of specificity.

Choreographic demands vary widely in terms of speed and direction of motion, weightbearing surfaces, and load bearing requirements. In general, the dancer must be ready to handle a broad range of movement skills. Agility and reaction time drills for weight-shift and level-shift tasks should be practiced, as should proper lifting techniques.

Thinness

In some female dance populations, disordered eating and menstrual dysfunction has been reported to be as high as 78% compared to 2% in the general population and between 10% and 60% (depending on the sport) among some populations of female athletes.[29] Hence, the clinician should take a menstrual history from all female dance injury patients and, if indicated, refer the dancer to appropriate psychological support services or gynecology-endocrinology services in order that the entire aspect of thinness as an occupational hazard is addressed.

Improving nutritional intake, restoring hormonal balance, and optimizing muscle mass are crucial for amenorrheic patients. When treating

fracture, osteopenia, or osteoporosis in the clinic, the rehabilitation specialist must take extra care to balance the benefits and risks of weightbearing exercise. While appropriate levels of weightbearing exercise have been noted to provoke bony hypertrophy, offset the loss of bone or, in some cases, actually increases bone mass among hypoestrogenic women, the intensity, frequency, duration of activity, and type of training that produce positive effects are still controversial.[107-109]

Patient-Therapist Interaction

Dancers, when learning movement, tend to be visual, musical, spatial, and kinesthetic learners and perceivers, and may use those pathways over verbal, logical, or interpersonal styles.[110,111] Although they may not be primary verbal learners, dancers must rely heavily on descriptive language for imagistic understanding of how to impose effort on movement in order to convey its dramatic intent. As such, carefully chosen language can be a powerful tool for the clinician when re-educating proper movement patterns.[7] Most dance terminology is based on the original French ballet vocabulary and it may take some time and powers-of-observation for the clinician to understand the movement function or complaint being presented by a dancer when being described according to this vernacular.

Dancers are most accustomed to learning movement through imagery, so combined use of visual, verbal, and kinesthetic coaching cues can be very useful in accomplishing rehabilitation goals.[112] Ideokinesis, for example, is a somatics technique developed by Sweigard,[113] which uses the declarative memory system to "mentally visualize imagery designed to facilitate improved neuromuscular coordination"[114] by creating moving images with directed, energetic, intentional lines of movement through specific anatomical sites to help the clinician achieve movement refinement. The use of image-based teaching cues calls upon dancers to increase their attention vigilence[115,116] and to actively participate in the reintegration process of their injury recovery by enhancing their sensory-motor awareness. Mental practice accelerates perceptual-motor organization, pre-movement organization (or strategy formations), and knowledge of movement relationships.[117]

Dance is concerned with effort (the qualities and energies of movement: flow, weight, space, and time) and with shape (the relationship between the body and the physical, as well as kinespheric, space the body occupies).[118] Re-learning dance movement depends upon not only regulated practice, but also upon the appropriate feedback of the results to the performer.[119]

Effectiveness of Rehabilitation

An effective dance rehabilitation program is one that gets the dancer safely and confidently back into her work setting. Clinicians must be able to assess the effectiveness of their treatment methods throughout the course of rehabilitation in order to successfully achieve this endpoint. Table 4 provides a few examples of the kinds of tests the clinician can create to obtain quantifiable measures of functional performance. The idea behind functional testing is that it can provide data about the dancer's tolerance for building block components of the basic ergonomic demands in her work environment. The clinician can use these tests to monitor the dancer's ability to safely endure incremental loading in a broader plan for progression. Such information can be useful in guiding treatment toward full workload demands.

True success of dance rehabilitation, however, can only be measured when athleticism and expression are fully reintegrated to successfully produce what we call dance. The creation of movement with the human body invariably involves an extremely complex interaction of often quite subtle movement, energies, and tensions as well as pointed

Table 4 Functional Tests for Dance[7]

Parameter	Example of Task	Score Unit
Balance	Romberg-type test	Time
Agility	Direction oriented, dance-specific reaction time drills	Number of successful completions with time limitations imposed
Concentration	Movement task with changing instructions in chaotic environment	Number of successful completions with sound and space distractions imposed
Proprioception	1. Balance tests – changing lights/surface 2. Proprioception tests	Time Goniometric accuracy: joint angle replication
Trunk Strength and Endurance	Pike sit-ups with mobile upper extremities	Number of repetitions without fatigue-induced movement errors
Trunk Power	1. Transfer of lower extremity weight 2. Efficiency of lower extremity placement following change in body level or directional facing	Number of stable transfers completed Number of successful foot placements with time dependent level or direction changes
Lower Extremity Strength	Unilateral limb "wall sits"	Time
Lower Extremity Power	1. Unilateral "sauté" jumps	Height and/or number of repetitions without fatigue-induced movement errors
	2. Unilateral "jeté" jumps	Horizontal distance

concentration and clear intention. Dance movement is purposeful in the realm of expression and relies on skilled motor control. It is only when the dancer is equipped with full physical capability, full concentration on the movement task at hand, and has full knowledge of, and independent strategies for, the maintenance of their health that rehabilitation is complete.

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