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Lower Back and Lower Limb Injury in Ballet Dancers: Incidence and Implications

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Literary Review of Dance Medicine Based Research

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By definition, ballet is a classical dance form characterized by graceful and precise movements and by elaborate and formal gestures, poses, and choreography. Classical ballet is the most disciplined form of ballet due to its adherence to traditional, highly formalized technique and its extreme expectations regarding placement and position of the human body.

Movements performed in ballet place extraordinary demands on the body in terms of endurance, muscular strength, muscular flexibility, joint stability, neuromuscular coordination, and integration of sensory stimuli. Individuals can begin classical ballet as young as desired since there is no recommended universal age requirement. As a result, young dancers are exposed to ballet technique as their anatomical structure is still growing, possibly causing stress and disruption to typical development. As a dancer increases technical ability, stress on muscles, bones, ligaments, tendons, and joints increases and rest time between class and performance decreases, which can lead to acute injury and possibly set a path towards chronic injury.

Dance medicine research has focused directly on causes and frequent locations of injuries common in the adult dancer. Research allows us to focus on the larger picture of what studies have achieved in the present in regard to dance training but questions still remain. In this review of literature, I will summarize what the body undergoes during a time of injury, discuss advances made in treating injuries common to dancers, consider methods of injury prevention, and also propose future direction for dance medicine research.

Dance medicine based research primarily uses cohorts of adult dancers who have a high level of expertise and prolonged exposure to ballet technique. By studying the body of an adult dancer, focus is placed on a fully developed human body or one that is almost fully developed. Published research in dance medicine has failed to focus on the impact of ballet on young and developing dancers. “Children are not miniature adults; rather they are in the process of growing.

Thus, they do not tolerate the same volume of activity as grownups."[1] Research shows very little of the influence ballet technique has on a developing body or the possible disruption to development that technique can cause. Often in ballet, young dancers who are identified as talented are asked to perform more complex roles and are encouraged to take an increased number of classes per week. This increase in technique exposure and stress on the body could increase the chances of injury on their growing frame but lack of research keeps that theory in question.

According to the limited studies addressing training risks in younger dancers, ballet technique can impact musculoskeletal development and cause disruption to standard bone growth via trauma to a growth zone epiphysis.[1] The growth zone epiphysis or epiphyseal plate is composed of hyaline cartilage and is situated at the ends of each long bone; this zone is solely responsible for the longitudinal growth of the bones. If this zone is fractured or damaged, growth may be atypical or halt completely, causing stunted growth or uneven development of symmetrical limbs.[2] Research also discusses numerous injuries possible for growing dancers such as Slipped Upper Femoral Epiphysis, Osgood-Schlatter's Syndrome, and Osteochondritis Dissecans without specifying cause, prevention, or treatment of these injuries in a growing human body.

In its consistent focus on adult dancers, research has traditionally neglected the impact of rigorous pre-professional ballet training on the young dancer. Potential areas for inquiry could be to discuss how extreme external rotation in ballet could possibly harm typical growth patterns. For example, does prolonged exposure to fifth position or plié cause stress and chronic pain as development continues in a young dancer? Another topic to consider in future research could be

[1] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.

[2] Brannigan, David. *Survey of Anatomy & Physiology*. 2 Ed. Dubuque: Kendall/Hunt Publishing Company, 2002.

whether or not ballet technique is too demanding on the immature body. These two possible research questions could be a way for researchers to prevent injuries in children or to tackle chronic injuries before the individual reaches an adult age. The population of dancing youth is large and constantly growing. Too many bodies may be at risk for injury and preventative measures could be taken if only dance instructors had more knowledge regarding the science of human movement and motor development. What guardian would knowingly subject their child to a methodology that is based solely on tradition and imitation as opposed to well-researched and reasonable pedagogical practice?

CAUSES OF INJURIES

Injuries, causes of injuries, and classifications of injuries are topics many dancers overlook in pursuit of their desired art. Children and adult dancers perform as they are told, often sacrificing kinesthetic awareness and anatomical clarity in their dance experience. Many dancers are subjecting their bodies to injuries unknowingly since they may be encouraged to disregard pain, subjected to instructor direction that emphasizes product over process, or driven to perfection making their eating and sleeping patterns inconsistent. "It has been reported that 85% of professional ballet dancers suffer an injury within a twelve month period,"[3] but understanding the causes and conditions of the injuries is often ignored. Causes of injuries can be categorized into four subheadings; **anatomical causes, lack of technical knowledge, poor teaching, and non-application of correct technique**.

Anatomical causes are injuries based on physical limitations that may prevent an individual from developing optimum technique. Examples would include limited external

[3] Twitchett, Emily. "Does physical fitness affect injury occurrence and time loss due to injury in elite vocational ballet students?." Journal of Dance Medicine & Science 14, no. 1 (2010): 26-31.

rotation of the hip (femur/acetabulum) or hyper-lordosis of the lumbar vertebrae. Anatomical causes are often not the fault of the dancer because it is influenced by an individual's anatomical structure. Dancers can only be responsible for acknowledging anatomical limitations and adjusting based upon that understanding if their knowledge and awareness is supported by their teachers.

Lack of technical knowledge regarding correct technique can predispose young dancers to injury while in the process of learning. While in class, students do not fully understand body placement and often try to place their body similarly to their more advanced peers, teachers, or demonstrators before they are technically ready, causing injury or stress on major points in the body. If a dancer forces hip rotation to a perfect one hundred and eighty degrees in first position because their teacher shows turnout in this manner, stress on the hips, knees, and ankles may develop.

Poor teaching can cause injury when an instructor places high demands on an individual or does not understand the physical limitations of a student. Ballet instructors often push students too hard or may fail to notice simple faults in technique that can cause injury over time such as improper sequencing through the foot, ankle, knee, and hip when landing from a jump or poor pelvic alignment and core support.

Lastly, **non-application of correct technique** is often where adult dancers experience injury more commonly. This involves injuries that occur due to a dancer not using proper technique when experiencing fatigue, psychological stress, or body overuse. Stressful performance schedules, long rehearsals, demanding choreography, and lack of sufficient sleep can all lead to chronic injuries as a result of non-application of proper technique.[4]

[4] Howse, J. Hancock S. *Dance Technique and Injury Prevention*. London: A&C Black, 1988.

VARIATIONS OF INJURIES

Injury can happen in three variations, with either injury to a muscle, a ligament or tendon, or a bone. All three of these injuries may be detrimental to the career and advancement of a dancer and can have recovery times ranging from several days to several months.

Muscle, unlike bone, has little capacity for regeneration from injury and healing of muscle tissue is in the form of fibrosis or scar tissue formation. Mature scar tissue is not comparable to muscle tissue because it is lacking in elastic quality. When a muscle stretches it causes the scar tissue to pull, possibly causing discomfort, tightness, and impaired movement. New scar tissue has very little tensile strength and is liable to tear, causing bleeding, inflammation, and the development of increased scar tissue. As the scar tissue increases, this may lead to a chronic condition that can restrict the use of the muscle group, strength of the muscle, and limit the overall range of motion. At about the twenty-day mark after an injury occurs, the scar tissue will have produced stronger fibroblasts, shortened the scar, and the injury will have recovered to around 80-95% of the original pre-injury state. Muscle repair, however, will also be dependent on the severity of the muscle strain.

Muscle strain can be categorized into three-degree levels, first degree, second degree, and third degree. First degree contains the mildest cases of muscle strain and is accompanied by low levels of pain and discomfort. An individual with a first-degree strain usually has a very slight reaction and no swelling of the affected area; recovery time can range from seven to ten days. Second-degree muscle strain involves moderate cases of muscle strain and is the result of tearing a portion of the muscle. The individual with the muscle strain will experience pain, swelling, and partial loss of muscle function; recovery time can range from four to six weeks depending on the severity of the muscle tear. Lastly, third degree muscle strain involves complete tearing of the

muscle, which may require an intervention of both surgery and physical therapy to allow for a full repair and recovery of the muscle. An individual suffering from third degree muscle strain will experience severe pain, swelling of the affected area, and major loss of function; recovery time can range from four to six months.[5]

Another form of trauma to the muscle is Delayed Onset Muscle Soreness (D.O.M.S.). "By definition, this condition is not immediately apparent and may not manifest itself until some hours after the activity."[6] Usually D.O.M.S. happens to dancers who are not in peak physical condition for the demands being made on the muscles. Results from D.O.M.S. are very noticeable the next day with pain and stiffness of the affected muscles. Causes are returning to class or rehearsal from a long lay-off from dance, undertaking an unfamiliar activity such as weight lifting, or having a practice with an unusually long duration of time or higher intensity. In moderate cases, muscle soreness occurs in the distal portion of the muscle near the junction of the muscle and tendon. In extreme cases of muscle soreness, the whole muscle can experience pain and stiffness for a few days. The cause of muscle soreness after physical activity is due to micro tears in the muscle fibers and damage to connective tissue, causing fluid buildup, pressure, an inflammatory response, and pain.[7]

Symptoms of D.O.M.S. follow a timeline that begins post exercise. One to three hours after exercising, evidence of soreness arises in the form of motor impairment, aches, possible cramping, and fatigue. One to three days after exercising, muscle stiffness, weakness, and pain with movement occurs, this part of the timeline is the most painful. Three to twenty one days after exercising is usually when pain and stiffness begins to decrease and the muscle returns to normal. Treatment for D.O.M.S. varies between individuals but usually involves massage and

[5] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.
[6] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.
[7] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.

light warm up activities. Participating in a warm down after dance, composed of light stretching and small movement may help minimize the effects of the activity on muscle soreness. "Massage to the areas affected will also hasten the removal of waste from the muscles and allow an earlier return to normal activities."[8]

After an injury to the musculoskeletal system occurs, a treatment plan of rest, ice, compression, elevation, and stabilization (R.I.C.E.S.) will help the muscle to heal accordingly and prevent further damage. An injury such as a hamstring muscle strain or sprained medial collateral ligament in the knee can be treated through R. I.C.E.S.

Rest prevents a dancer from furthering the injury or aggravating the injured area. "If it hurts to perform an action, then the dancer must not perform. Dancing through an injury will make the original injury worse, will slow down the healing process and may become a chronic or permanent condition."[9] Dance instructors should encourage students to attend class but not participate until the injury is fully healed and the individual is ready to return to dance.

Ice has been documented to help during the healing process of an acute injury because it limits increased fluid pressure by lowering metabolism and decreasing secondary effects of injury. Most blood vessels on the muscle heal themselves within minutes of being injured but the use of ice prevents further hemorrhaging. When using ice for injuries, it should be applied for approximately twenty minutes every two hours for the first seventy two hours of the injury.[10]

Compression and the use of ice should be used within the same time frame to reduce fluid buildup. Compression of an injury is beneficial for limiting and controlling edema during the acute stage of an injury. Edema is the abnormal accumulation of fluid beneath the skin which needs to be correctly handled; incorrect applications of compression can do more harm to the

[8] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.
[9] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.
[10] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.

injury. The use of compression should be tight but not tight enough to restrict blood flow to the injury. [11]

Elevation of the injured limb can help prevent swelling. When elevating a limb, the height level should be above the cardio-thoracic area of the body. Achieving this height level will help with blood circulation and prevent blood from pooling in the injured area.[12]

Lastly, stabilization refers to the use of a sling, sports tape, or strapping to assist with treatment, help limit pain, and prevent unnecessary, damaging movement. Stabilizing the injury does not require the immobilization of the limb or affected area. Immobilization can affect the drainage process away from the injured area, causing atrophy, limiting neural responses, and lengthening the overall healing period. There are a variety of receptors within the joints, tendons, ligaments, and muscles that respond to mechanical stress and movement such as muscle spindles, Golgi bodies, and free nerve endings. "The inhibition of these responses due to immobilization leads to a much longer recovery period than if some movement is encouraged in the acute stage of injury."[13]

Injury to muscle is very similar to injury of a ligament or tendon. All three are considered variations of connective tissue and heal by fibrosis or scar tissue formation. Differences are distinguished by their function within the body; muscles are contractile tissues responsible for producing force and causing motion while tendons attach bone to muscle and ligaments are responsible for attaching bone to bone.[14] Average recovery time for an individual suffering from a ligament or tendon injury is about four months but progress could potentially be slowed due to

[11] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.
[12] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.
[13] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.
[14] University at Buffalo Department of Orthopaedics, Biomechanics Lecture. "Ligaments and Tendons." http://wings.buffalo.edu/eng/mae/courses/417-517/Orthopaedic%20Biomechanics/Lecture%203u.pdf (accessed 2011).

additional complicating factors. Recovery time for ligaments and tendons, like muscle, is dependent on the severity of the injury; a small tear will have a shorter recovery time as opposed to a complete tear that needs to be repaired with surgery.

Lastly, skeletal or bone injury is the lesser of the three to be found in the ballet population but damage to the skeletal system still accounts for about 22% of all dance related injury. [15] Dancers usually experience stress fractures to the bone as a direct result from prolonged or repetitive loading of the bones in the lower body. The most common injury sites for stress fractures among dancers is within the metatarsals of the foot, mainly metatarsal II, the calcaneus, the navicular, and the fibula and tibia of the lower leg.[16]

Almost immediately after a break, the body begins a four step process in order to have the bone regenerate itself. Initially after the break, the fissure of the bone severs the blood vessels that run alongside the bone shaft, causing a clot known as a fracture hematoma. The hematoma will stabilize the bone and prepare the two sides for mending while tiny blood vessels grow from the hematoma to support the beginning of the healing process; this is the first phase of bone fracture healing. The second phase occurs after several days when the hematoma forms in to a tougher consistency known as a callus. Cells known as fibroblasts begin producing collagen, a major protein found in bone and connective tissue, sparking the formation of fibrocartilage. This then transforms the callus in to a tougher fibrocartilaginous callus, which will bridge the two pieces of severed bone together. The third phase begins when immature bone cells known as osteoblasts move in and begin producing mature bone cells, forming the fibrocartilaginous callus in to a bone callus. This phase can range from three to four months and allows the bone to enter in to the fourth and final phase of healing. During the fourth phase, osteoblasts and osteoclasts

[15] Shan, Gongbing. "Comparison of repetitive movements between ballet dancers and martial artists: risk assessment of muscle overuse injuries and prevention strategies." Research in Sports Medicine 13, no. (2005): 63-76.
[16] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.

work together for months to allow the bone callus to be filled in with tougher compact bone. The bulge in the bone due to the callus will also gradually decrease, returning the bone to its original shape. Blood circulation continues to improve while nutrients such as calcium and phosphorus will continue to strengthen the bone; this completes the bone healing process.[17]

When referring to fractures within the body, it is also important to understand the various types of fractures that can occur. When injuries take place in an individual's body, many people do not understand the severity or medical terminology used by their physician. When it comes to bone injury, many physicians hope for a clean break, known as a simple fracture. A simple fracture is when the bone is cleanly broken in one area and has suffered no other trauma. Other breaks that are not as easily mended are compound fractures, when the broken bone punctures the skin or an impacted fracture, when one end of the fractured bone is driven in to the other portion of bone. A comminuted fracture refers to the type of fracture where part of the bone shatters in to fragments and a greenstick fracture refers to a child's bone bending and cracking but not fully breaking.[18] By understanding types of injuries and processes of the regeneration of muscle, ligament, tendon, and bone, an individual can be prepared for the recovery journey ahead and understand the physiological healing taking place within the human body.

Being informed in regards to injury is important for dancers because it empowers the individual to ask questions and understand what to expect regarding injuries that are typical or reoccurring in the dance population. Although this knowledge is helpful, having a relationship with a general physician or an orthopedic physician, which is a branch focused on the musculoskeletal system. "In a recent study in 2005, it was shown that less than 50% of dancers

[17] Lamb, Robert. "Discovery Health: How Do Broken Bones Heal?." http://health.howstuffworks.com/human-body/systems/musculoskeletal/heal-broken-bones2.htm (accessed 2011).
[18] Lamb, Robert. "Discovery Health: How Do Broken Bones Heal?." http://health.howstuffworks.com/human-body/systems/musculoskeletal/heal-broken-bones2.htm (accessed 2011).

seek care from physicians. There is an overall mistrust in the dancer population of physicians, which often stems from a fear of being misunderstood or being ordered to stop dancing."[19] Ideally, the physician will be an experienced diagnostician who understands the demands of dance on the body and can guide the dancer through a carefully considered rehabilitation or prevention program.

In the following discussion, I will review research regarding common injuries of the lower spine and lower limbs within the dance population.

[19] Gottschlich L, Young C. "Spine injuries in dancers." Current Sports Medicine Reports 10, no. 1 (2011): 40-44.

INJURIES OF THE SPINE

The human spine, also known as the vertebral column, consists of twenty-four articulating vertebrae (intervertebral discs between) and nine fused vertebrae. The top section of the vertebral column is composed of seven articulating vertebrae, known as the cervical region. The second section of the vertebral column is composed of twelve articulating vertebrae, known as the thoracic region. Each of the twelve thoracic vertebra and their transverse processes articulates with a rib to form the thoracic cavity. The third section, composed of five articulating vertebrae is known as the lumbar region. These five vertebrae are the largest in size due to the need to support the most weight. The fourth section, composed of five fused vertebrae is the sacrum. The last section of the vertebral column, the coccygeal region, is composed of three to five fused vertebrae and is commonly known as the 'tailbone.' Both the sacrum and coccyx are fused with maturity and have no intervertebral discs situated between the vertebrae. The vertebral column is located in the dorsal cavity of the torso. It is active in blood cell production and mineral storage. It also functions to protect the spinal cord, serve as a base of attachment for tendons, ligaments, and muscles, and provides structural support, flexibility and mobility.

Scoliosis

Scoliosis involves a deformity of the spinal segments with lateral curvature and vertebral body rotation. Scoliosis can occur in any region of the vertebral column and is categorized differently depending on the age of onset – congenital, infantile, juvenile, adolescent, and adult. The cause of scoliosis can be either idiopathic (occurring spontaneously), occur as a result of a preexisting condition like cerebral palsy, or can result from abnormal development of the spine

in utero. "In dancers, adolescent idiopathic is the most common type and is characteristic in patients eleven years old to growth completion."[20]

Scoliosis has a higher prevalence in the dance population and occurs equally in males and females, although curvature progression is more frequently seen in female cases. "In ballet dancers, delayed menarche and prolonged episodes of amenorrhea have been suggested as predisposing factors for scoliosis."[21] During a physical exam, it is important to elicit the patient's menstrual history as well as perform several tests and observations to correctly diagnose and treat scoliosis.

Typically, a physical exam begins with gait testing and checking the patient's body symmetry. When examining the spine, observing shoulder height asymmetry, prominent scapula, protruding ribs, and asymmetric iliac crest heights may signify dextroscoliosis (curvature to the right) or levoscoliosis (curvature to the left). After examining symmetry at various levels, evaluating the patient's range of motion in lumbar flexion, extension, and lateral rotation as well as performing an Adam's Bending Test can further the diagnosis of scoliosis. If tests are positive, scoliosis can be diagnosed accurately and treatment may begin.[22]

"Treatment of scoliosis typically falls into one of three possible options: observation, orthotics, or operative management. The choice of treatment option depends on the severity of the curve."[23] If the curve is less than twenty degrees, observation of curvature progression and physical therapy treatment is used. Physical therapy will focus on exercises for flexibility, joint mobilization, stretching and strengthening, proper postural alignment, and biomechanical alignment for dance and everyday activities.

[20] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[21] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[22] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[23] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.

If the curvature is between twenty and forty degrees, treatment through orthotics is encouraged and include custom molded cervical-thoracic-lumbar-sacral orthosis (CTLSO or Milwaukee Brace) or thoraco-lumbosacral orthosis (TLSC or Boston Brace). These custom molded orthotics are worn twenty three hours per day until the end of the individual's growth spurt. Effectiveness of bracing is dependent on patient compliance and it is important to promote wearing the brace as often as possible, even during dance activities. If the curve is greater than forty degrees, surgical correction is indicated and usually occurs with spinal fusion.[24]

Spondylolysis

Spondylolysis is defined as being a defect in the typical bony structure between the superior and inferior articular processes, also known as pars interarticularis of the vertebrae. It is most commonly seen in the lumbar spine and is due to microtrauma from repetitive hyperextension and rotation of the lumbar spine. Dancers often cause stress to the lumbar spine during a position known as 'cambre' when the lumbar spine is in a state of extreme hyperextension or during arabesque or attitude. When the leg is involved in extension greater than ninety degrees, this causes stress to the lower back and pars interarticularis, which may cause a stress fracture of the lumbar spine. This condition often has a greater incidence in female gymnasts and Caucasian dancers but it is also thought to have a hereditary predisposition as well.[25]

An individual suffering from spondylolysis will complain of lower back pain that may be localized to an affected side or throughout the lower back. The pain may be worse when performing an arabesque, attitude, or during grand battement derriere. Pain is not usually

[24] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[25] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.

accompanied by numbness, tingling, weakness, or radiating pain. During a physical exam, the physician will observe the range of motion in the lumbar spine. Dancers usually have above average flexibility in the spine so limited range of motion may not be elicited. Pain levels in positions such as arabesque and attitude should also be checked. "Pain elicited with extension is spondylolysis in a dancer or gymnast until proven otherwise."[26]

To medically prove spondylolysis, radiographs should be taken to detect stress fractures of the pars interarticularis and a CT scan can also show detailed evidence of fractures or other bony pathology. When diagnosis has been proven, a course of action can be prescribed for the individual. For acute spondylolysis, immobilization of the affected area with bracing and physical therapy is recommended. The brace is worn in neutral lordosis of the spine and is expected to be worn for twenty three hours per day until the individual's symptoms subside. Physical therapy should involve stretching the hamstrings, iliopsoas, paraspinals, and abdominal muscles. Physical therapy should be able to accommodate the brace accordingly. The fracture may not heal completely according to medical standards but as symptoms resolve, the individual may be able to return to dance activity.[27]

[26] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[27] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009

INJURIES OF THE HIP

The human hipbone consists of three parts: the pubis, the ilium, and the ischium. The fused bones are joined together at the front at the pubic symphysis and in the back where the ilium articulates with the sacrum on both sides. The joint of the hip is formed between the acetabulum and the head of the femur and is stabilized by five ligaments. These ligaments allow movements such as flexion, extension, abduction, adduction, lateral and medial rotation and circumduction of the hip. Nerve supply to the hip region originates from the lumbar and sacral plexi, including the sciatic nerve, the largest nerve within the body. [28]

Trochanteric Bursitis

Trochanteric bursitis, seen more commonly in females, can develop acutely, gradually, or from direct trauma to the hip.. Trochanteric bursitis develops as an inflammation of the bursa over the greater trochanter and is a common cause of hip pain in the dance population. In dancers, trochanteric bursitis is associated with overuse in combination with poor biomechanical alignment. Because of trochanteric bursitis, a dancer may experience lumbosacral radiculopathy, scoliosis, snapping hip, or leg length differences.[29]

The individual experiencing trochanteric bursitis will complain of localized pain over the greater trochanter and lateral thigh area. Pain can be worse with standing from a seated position, prolonged standing or walking, ascending stairs, or sleeping on the affected side. During a physical exam, manually feeling the affected area of the greater trochanter will usually lead to

[28] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.
[29] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.

point tenderness and examining the hip and lower back range of motion may confirm a case of trochanteric bursitis.[30]

Treatment of trochanteric bursitis includes a trial of oral non-steroidal anti-inflammatory drugs (NSAID) such as aspirin, ibuprofen, or naproxen to treat inflammation and pain. Local corticosteroid injection into the affected bursa can also relieve pain alongside taking a NSAID. A course of physical therapy to focus on stretching the iliotibial band, the tensor fascia latae, external hip rotators, hip flexors, and quadriceps should be followed in addition to medication.

Coxa Saltans (Snapping Hip Syndrome)

Coxa Saltans, or snapping hip syndrome, can be classified into three sources: external, internal, or inter-articular. External snapping can be caused by the iliotibial band, tensor fascia latae, or lateral gluteus maximus sliding over the greater trochanter. Internal snapping is most common in female dancers under the age of twenty and is caused by the iliopsoas sliding over the iliopectineal eminence, femoral head, femoral neck, or lesser trochanter. Internal snapping can also be associated with iliopsoas bursitis or iliopsoas tendonitis, which is inflammation of the synovial membrane near the insertion of the tendon on the femur. Intra-articular snapping is caused by loose bodies, labral tears, or osteochondral fractures.[31]

The individual will usually complain of an audible snapping or clicking of the hip joint with movement involving flexion, abduction, external rotation, and grand plié. The snapping is often painless but in some cases pain can occur right before or during the snap. Snapping of the hip occurs asymptomatically and can continue for months or years without causing pain. During a physical examination, manually feeling the affected area, eliciting an audible or palpable snap,

[30] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[31] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.

and testing iliopsoas strength by testing resisted hip flexion may help to better understand the snapping.[32]

Treatment of Coxa Saltans that does not cause pain begins with correcting alignment, muscle imbalance, proper biomechanics, and gait training. Incorporating hip flexor, hip abductor, and hip external rotator stretching exercises may decrease clicking over time. For acutely painful Coxa Saltans, NSAID's can be taken to minimize pain and inflammation alongside a course of physical therapy. Physical therapy should focus on functional training and the individual should eliminate strenuous dance activities until symptoms have subsided. Surgical intervention for a dancer with Coxa Saltans should be avoided at all costs because it may permanently end a dancer's career.

Osteoarthritis

Today, twenty-seven million people suffer from osteoarthritis. The cause of it is unknown and there still currently is no cure.[33] In the dance population, arthritis develops earlier than in the general population and can be classified as either primary or secondary. Primary arthritis usually refers to an onset of arthritis without any causation or origin. Secondary arthritis can develop as a result from trauma or injury. With dancers, repetitive microtrauma to the hip joints can lead to an onset of secondary arthritis. Osteoarthritis is a degenerative process affecting articular cartilage of the synovial joints, often affecting the areas of the knees, hips, and hands. Due to microtrauma, small tears develop in the joint cartilage, which progress to larger tears causing the cartilage to fray into small fragments.[34]

[32] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[33] Arthritis Foundation, Arthritis Disease Center. "Osteoarthritis." 2011.http://www.arthritis.org/disease-center.php?disease_id=32
[34] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009

Damage to the cartilage can lead to a loss of shock-absorbing, lubricating, and nourishing properties of synovial fluid that surround bone, ligaments, and tendons. Because of this loss, joints have to bear the load of force and elicit pain in response. Pain can come from activating nerve endings surrounding the synovium due to excess pressure or from an engorgement of subchondral bone, muscle fatigue, or contraction of the joint. A patient suffering from osteoarthritis will complain of gradual pain with or without prior injury. Pain can be worse with activity, relieved with rest, and may be associated with morning stiffness.[35]

Examining for osteoarthritis can differ according to the stage of the disease. In the early stages of the disease, gait may appear abnormal but the joint itself may appear to be typical. As the disease matures, range of motion will decrease and hip flexion, adduction, and prone rotation will become difficult. If osteoarthritis is in the early stages, radiographs will come back as negative but as maturing continues, radiographs may be used to properly observe the extent of the degeneration.[36]

Treatment should begin with understanding osteoarthritis and explaining it as an inevitable byproduct of aging and a lifetime of dancing. To manage osteoarthritis, changes in diet should be recommended first. Appropriate strategies include increasing water intake to hydrate the body, and increasing fruits, vegetables, and cold-water fish. It is also important to limit the consumption of red meat and processed foods. Following a course of physical therapy that targets lower limb stretching and strengthening, core exercises, aerobic conditioning, and low weight-bearing exercises could also be beneficial. In extreme cases, surgery through joint reconstruction, arthroplasty, or total hip replacement may be prescribed. The advantages of these procedures are presently debatable.

[35] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009
[36] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009

INJURIES OF THE KNEE

The knee is the largest joint within the human body and is involved in a larger variety and number of injuries. It is a modified hinged joint with its main movements being flexion and extension with some outward rotation in the flexed position. The knee is an incongruent joint (meaning pieces do not fit snugly together), the incongruence is counteracted by a relatively thick cartilaginous covering by the lateral and medial meniscus and by synovial fluid.[37]

The articular portions of the knee consist of the femoral condyles, the tibial condyles, and the patella (kneecap). The upper portion of the patella serves as an attachment of the quadriceps tendon and the lower portion of the patella serves as the origin for the patellar tendon. The major muscles of the knee joint consist of the quadriceps group, hamstring group, gracilis, sartorius, and popliteus.[38]

The synovial membrane within the knee lines the inside of the fibrous capsule of the joint and provides lubrication to the joint. "The fluid is secreted at the periphery of the joint and is swept across the joint by movement and the villi to deliver the fluid deeply between the surfaces. The fluid also contains the nutrition for the articulating cartilage."[39] When injury to the knee occurs, the synovial fluid floods the joint to act as an anti-inflammatory and as a protective measure.[40]

Patellar Tendonitis (Jumper's Knee)

While jumping and specifically landing from a jump, the patellar tendon undergoes significant stress. When the knee is flexed during landing, the patellar tendon experiences the

[37] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.
[38] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.
[39] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.
[40] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.

greatest degree of stress at the insertion site. In dancers, having tight quadriceps and hamstring muscle groups along with poor landing technique overloads stress on the patellar tendon. Over time, the patellar tendon develops chronic inflammation and degenerative changes from repetitive trauma. Because of this trauma, dancers develop patellar tendonitis, also known as jumper's knee.[41]

An individual suffering from patellar tendonitis will complain of an aching, dull pain that gets worse when landing from jumps in ballet activities. Usually the pain is anterior to the knee and inferior to the patella. Patellar tendonitis is described as having a gradual onset without a specific time of onset or preceding injury. During a physical exam, patients may experience tenderness and pain inferior to the knee. If pain is superior to the patella, the quadriceps tendon may be involved. Patellar tendonitis can be classified into four stages. "Stage I involves pain following activity, without affecting performance. Stage II involves pain during and following activity, without affecting performance. Stage III involves pain during and following activity and affects the quality of performance. Stage IV involves pain, inability to completely extend the knee, a sensation of the knee 'giving way' and may reflect a partial tear of the tendon."[42]

When patellar tendonitis is diagnosed, a treatment plan can begin. First a dancer must be instructed to decrease or eliminate dance activity that aggravates pain and increases the load placed on the patellar tendon. Recovery time and treatment depends on the severity of the stage of injury. Initially a course of rest, ice, compression, elevation, and stabilization will be helpful for stages I-IV of patellar tendonitis. For stage I injuries, a course of non-steroidal anti-inflammatory drugs can be taken for pain and inflammation along with painless stretching and use of plyometric and joint proprioceptive training. For stages II and III, a longer period of rest is

[41] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[42] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.

recommended alongside using an appropriate alternative to strength training and cardiovascular fitness to prevent deconditioning while out of dance activities. For stage IV, surgical intervention is used and involves drilling and resectioning of the pole and partial removal of dead, damaged tissue of the involved tendon. [43]

Meniscal Tear

A tear to the medial or lateral menisci of the knee is the most common injury in dancers as a result of increased flexion and force at the joint. The medial and lateral menisci are "C" shaped bodies of fibrocartilage located between the tibial plateau and the femoral condyles. The function of the menisci is to act as a shock absorber to distribute the load of force through the knee joint during flexion and extension. It also lubricates the knee joint, reduces friction and protects the femoral and tibial articular surfaces. In dancers, meniscal tears may result from forcing turnout or from direct trauma involving incorrect landing from jumps with a valgus (promotion) or varus (supination) force applied to the knee. A valgus force applied to the knee can cause a medial meniscal tear while a varus force can cause a lateral meniscal tear.[44]

An individual will complain of pain over the medial or lateral joint line of the knee. Pain will also be accompanied by the inability to completely flex or extend at the knee. Experiencing a 'buckling' or locking of the joint may reflect a fragment of torn cartilage that may be lodged within the joint itself, limiting movement and causing pain. If the tear is minor, a level of pain may go unnoticed until time has passed and activity has furthered the meniscal injury. During a physical examination, decreased range of motion and joint line pain should be observed as well as running tests to localize meniscal movement. The McMurray Test is performed by externally

[43] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[44] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.

rotating the tibia with a valgus force applied to the knee. An audible or palpable snap, click, or pop reflects a probable tear of the medial meniscus. The Apley Compression Test is performed by placing a downward force on the knee joint while externally and internally rotating the tibia. Pain with compression to the knee reflects a meniscal tear. A Magnetic Resonance Image (MRI) of the knee joint can accurately diagnose the meniscal tear as well as associated ligament, cartilage, and/or bone injury.[45]

Initially, injury should be treated with rest, ice, compression, elevation, and stabilization to reduce pain and inflammation of the knee. NSAID's can also help to reduce pain and swelling post injury. After pain resolves, a course of physical therapy to restore range of motion and strengthen muscles around the knee could be beneficial. If the patient's pain improves within four to six weeks, a gradual return to dance can be encouraged. If pain, inflammation, and locking of the joint persists,[46] surgical measures may be recommended. Surgical intervention involves either arthroscopic repair or removal of the meniscal tear. During surgery, care is taken to preserve as much healthy cartilage as possible to avoid future injury and degenerative changes within the knee joint. In the past, a meniscal tear could end a dancer's career. With today's modern medicine, a meniscal tear can be treated within weeks and a long career may ensure.

[45] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[46] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.

INJURIES OF THE ANKLE AND FOOT

The foot is a weight bearing structure responsible for locomotion of the human body. The ankle joint is a hinge joint between the tibia, fibula, and talus permitting flexion (flexed foot/dors flexion) and extension (pointed foot/plantar flexion). The ankle and foot are comprised of seven tarsals, (talus, calcaneus, cuboid, navicular, and three cuneiform bones) five metatarsals, and fourteen phalanges.[47]

Acute Fracture of the 5th Metatarsal Distal Shaft (Dancer's Fracture)

Acute fracture of the fifth metatarsal is the most common acute fracture in the dance population. This fracture commonly occurs as a result of twisting the forefoot in a fixed position. This can occur from rolling over and falling from a demi pointe position with the ankle joint in a full plantar flexion or from landing incorrectly out of a jump. This results in either an oblique, displaced, or comminuted fracture that has a distal, lateral origin and progresses proximally and medially. Lateral leg weakness and ankle instability can also predispose a dancer to this type of foot injury.[48]

In dancers, this injury is often more prevalent during performances or rehearsals. The individual will complain of pain and swelling over the lateral forefoot after movements similar to those stated above. Pain and bone tenderness are experienced along the fifth metatarsal and can be associated with swelling, decreased range of motion, and weight bearing difficulty. Radiographs should be taken of the foot to properly diagnose the injury and assess bone displacement.[49]

[47] Kapit,Wynn. The Anatomy Coloring Book. 3 ed. Amy Teeling. Glenview: Pearson Education, 2002.
[48] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[49] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.

Initially rest, ice, compression, elevation, and stabilization should be used to reduce swelling. Rest and time off from dance activities are important to allow the injury to fully heal and prevent further injury to the metatarsal. If the fracture is minimally displaced or non-displaced, a removable walking boot can be worn with progression to full weight bearing movement within three to four weeks. If the fracture is mildly displaced, a short leg cast with weight bearing for six to eight weeks is recommended. In rare cases, the fracture is largely displaced and, surgical fixation may be prescribed.[50]

Hallux Valgus

Hallux valgus refers to the most common osteoarthritic joint of the foot and the most common pathologic condition of the big toe. Hallux valgus is one of the most painful conditions of the foot and can occur equally in the dancing population and the general population. Although hallux valgus can be present in both populations, dancers typically suffer from the condition at an earlier age. Also known as a bunion, it occurs when the big toe (hallux) is forced towards the second toe causing inflammation at the base of the big toe. A bunion is a progressive condition in which the fluid of the bursa at the first metatarso-phalangeal joint becomes inflamed. A toughened area of skin, or callus, usually forms in the center of the bursa causing discomfort and sometimes even excruciating pain.[51]

Hallux valgus is caused by the failure of the muscles responsible for keeping the hallux in line. These muscles are the flexor hallucis longus and brevis, extensor hallucis longus and brevis, and adductor hallucis. Strengthening muscles of the hallux will keep the toe in proper alignment but stress to the adductor hallucis will weaken and lengthen the muscle causing other Hallux

[50] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[51] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.

muscles to shorten and tighten. This stress to the muscles forces the big toe towards the smaller toes of the foot, beginning the hallux valgus condition.[52]

Hallux valgus can be caused by a number of dance activities as well as wearing narrow fitting shoes or having a genetic predisposition. In dancers, it often a results from repetitive pronation in externally rotated positions or while attempting to unnaturally increase turnout by drilling feet into the floor with no awareness regarding proper hip external rotation, knee alignment, or foot alignment. In ballet technique, 180° external rotation of the hip joints (femur/acetabulum) with alignment of the patella over the second toe while maintaining a lifted, supported arch of the foot is ideal.

The human body is typically not built to support extreme turn-out and very few people have the ability to master this 'ideal' technique. "Dancers who do not have a significant degree of external rotation at the hips tend to compensate by trying to force external rotation at the knees, ankles, and feet with abnormal 'wrenching' of the joints."[53] As the dancer forces the external rotation of the hips, the knee and foot will accommodate the position. Bunions are formed as a result of repetitive loading of the feet in a pronated turned out position.[54]

Individuals suffering from hallux valgus will complain of a gradual onset of pain over the ball of the foot or over the medial portion of the first metatarsal head. Usually bunions develop well before pain is noticed. When pain arises, it is usually worse with weight bearing, jumping, or after classes and rehearsals. The pain can become worse with increased pressure over the affected area; this may include manually touching the area.[55]

[52] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.
[53] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[54] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.
[55] Bracilovic,Ana, MD. Essential Dance Medicine. Grant Cooper, Joseph Herrera. New York: Humana Press, 2009.

While examining the hallux, assess the range of motion of the metatarso-phalangeal joint in the hallux valgus position as well as in an anatomical position. It is also essential to examine the individual's alignment in basic technical dance positions at the hip, knee, and ankle because hallux valgus results from poor technical alignment and biomechanics that dancers are unaware of. Once the dancer is examined, radiographs should be taken of the foot in weight bearing positions. If the hallux valgus is caught in the early stages, recommending a wider boxed pointe shoe, foot orthotics, or the use of toe spacers may help with toe alignment and prevent progression of the injury. Massaging the foot may also help with pain and discomfort but massaging should be deep tissue and include flexion and extension of the toe. Surgery is often used as a last resort because it can increase stiffness of the joint and decrease overall range of motion within the metatarso-phalangeal joint. Surgery may help due to an onset of osteoarthritis in the joint in addition to a buildup of fibrous tissue and chronic inflammation.[56]

Flexor-Hallucis Longus Tendinitis

Flexor hallucis longus tendinitis is one of the most common tendon injuries in ballet dancers and it is commonly known as 'Dancer's Tendinitis.' Overuse of the ankle, repetitive pronation of the foot, sickling in a releve′ or pointe position, and improperly landing from a jump can all cause injury to the flexor hallucis longus.

The flexor hallucis longus (FHL) is involved during both plantar flexion and dorsiflexion of the ankle, during takeoff

and landing from jumps, and is also responsible for contributing to proper alignment. In the ankle, the FHL is compressed over the posterior talar tubercle during plantar flexion and is

[56] Caldwell, Chris. *Dance and Dancers' Injuries*. Gloucestershire: Corpus Publishing Limited, 2001.

stretched between the posterior talar tubercle and the sustentaculum tali during dorsiflexion. When jumping, the FHL is the last tendon to contract while taking off for a jump and it is the first tendon to engage when landing from a jump. Lastly, the FHL is a stabilizer for the subtalar joint against pronation of the foot, so when pronation occurs, the FHL becomes strained. Any repetitive movements from poor technique, weakness, or instability will cause trauma to the tendon, especially when on pointe.[57]

An individual suffering from flexor hallucis longus tendinitis will complain of posterior or medial pain in the ankle that may be accompanied by a clicking sound coming from the ankle. Having the big toe lock while on demipointe or having the big toe elicit a clicking sound during flexion or extension is also a frequent complaint. While inspecting the FHL, palpate the area for tenderness and swelling as well as check for overall range of motion. A physical assessment may not be sufficient in the diagnosis. Ordering radiographs or an MRI may also aid in ways an assessment cannot.[58]

Treatment for flexor hallucis longus tendinitis is common to most other athletic based injuries. NSAID's can be taken to decrease pain and inflammation of the tendon as well as undergoing ice massages or cold whirlpools for comfort. While being treated, dance activity and pointe work should be avoided to allow the tendon to recover from repetitive overuse. A course of physical therapy can also be helpful by strengthening stabilizer muscles, core control, and possibly fixing poor technical habits. If the FHL tendonitis is extreme, surgical intervention may be recommended. If the tendon's muscle fibers have become inflamed and thickened to the point where normal movement is impaired, a surgical thinning of the muscle and tendon is required.

[57] Nachazel, K. (2002). Mechanisms and treatment of tendinitis of the flexor hallucis longus in classical ballet dancers. Athletic Therapy Today, 13, 13-15.
[58] Nachazel, K. (2002). Mechanisms and treatment of tendinitis of the flexor hallucis longus in classical ballet dancers. Athletic Therapy Today, 13, 13-15.

After surgery, the foot and ankle are immobilized for four to six weeks with a full recovery usually in three to five months.

In conclusion, I have found that researchers need to bring more focus to the cause of poor technique in the dance population. Further research studies should be centered on the need for understanding musculoskeletal injuries in young dancers, possible preventative measures, and education for dance instructors.

Dancers often believe that stretching a few minutes prior to class, rehearsal, and performances is adequate to prevent injuries but according to the dance medicine research I have explored, those few minutes are not enough to fully prepare muscles for activity. Could yoga or Pilates for dancers strengthen overused muscles or integrate muscles that are not as strong because of neglect due to dance? Possibly the idea of resistance training or light weight training could be studied in its usefulness to help dancers prevent injury or strengthen bones to avoid frequent stress fractures or osteoarthritis. Dancers are often concerned with the idea that their bodies are delicate and frail, only relying on dance exercises to tone and activate the muscles within the body. Should dancers expand their minds to the idea of incorporating cross training, cardiovascular, and resistance training to support their dance technique?

Regarding education for dance teachers; should teachers have to undergo proper training or certification in order to lead a class with health and science in mind? From learning about continuous injuries due to poor teaching or lack of knowledge, I truly believe instructor education should be enforced. Having a background in kinesiology, anatomy, human development, and biomechanics can help an educator shape his or her lessons according to an anatomical structure. Holding uneducated men and women responsible for numerous young bodies without any awareness of the human body and movement is increasing the amount of injured dancers that suffer from acute and chronic injuries. An artist can be judged on the basis

of talent alone but an educator should understand the science and art of dance pedagogy before attempting to guide the development and progress of young dancers.

Dance is an art form where the body is used to convey expression and is often seen as universal tool. Incorrect dance technique, poor teaching, and lack of technical knowledge can make ballet training damaging and dangerous. Dancers becoming educators once they are close to retirement from the stage is not adequate training. Parents and young dancers place trust in the hands of their teachers but the art form fails them without an investment in kinesiological and anatomical understanding of the human body. If further research was devoted to injury prevention, appropriate pedagogical practice, and biomechanical understanding of the stresses on the developing body, the toxicity of the technique may decrease, paving a way to awareness and longer careers in dance.

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