THE INTERCONNECTEDNESS OF DANCE AND MUSCULOSKELETAL PHYSIOLOGY

By

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A Thesis Submitted to the W.A. Franke Honors College

In Partial Fulfillment of the Bachelor's Degree With Honors in

Physiology & Medical Sciences

THE UNIVERSITY OF ARIZONA

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Abstract:

Dance is a unique form of self-expression that has a multitude of physiological implications pertaining to both health and injury. The purpose of this project is to emphasize the relationship between dance and musculoskeletal physiology. The project includes a self-choreographed contemporary dance performance and a written analysis of the physiological components responsible for the execution of a variety of technical dance elements. Misuse of certain muscles can also increase a dancer's susceptibility for injury. Thus, the text includes descriptions of how these injuries may occur and the mechanisms by which they can be avoided. Lastly, dance has a variety of positive impacts on the body, which are discussed in the final section of the paper.

Preface:

My name is Sarah Courtney, and I am a senior at the University of Arizona earning a degree in Physiology & Medical Sciences with a minor in Spanish. I have been a dancer since the age of three. I have received classical training in the principal dance genres, performed at a variety of venues (i.e., local parades, high school and professional sporting events, school assemblies, etc.), and competed at the regional and national levels. Although I decided not to pursue dance as a career, I continue to cultivate my love for the art form as a member of Ardor Dance Company, a contemporary dance group on campus.

Throughout the creation of this project, I have been able to combine two of my passions—dance and physiology. The interconnectedness of these two disciplines is prominent. Amidst my physiological studies, I have noticed significant changes in how I approach technical dance movements. During my training throughout middle school and high school, I learned the names of some muscles that are essential for the execution of certain dance skills. However, I never fully understood how to maximize the use of these muscles, or their connections to other bodily components, until I became a physiology student. The information taught in my courses has been integral in my avoidance of dance-related injury and the continuation of my artistic growth despite my aging body.

One component included in this honors thesis project is a self-choreographed dance piece. While creating this piece, I thoroughly considered the physiological implications of each technical and artistic movement. The other component is the written section which includes an analysis of the muscles and skeletal components involved in the execution of several technical elements that can be observed in the choreographed piece. Additionally, I include comments on the benefits of dance as it pertains to physiological health and aging.

Introduction

Although many may think of dance solely as an artistic pursuit, dance also has significant scientific implications. For instance, dance has been found to improve many components of physical health, including blood biomarkers, muscular and skeletal system function, and body composition.[5] Dance has been shown to enhance heart rate and is correlated with prominent levels of enjoyment amongst participants, thus improving physical and mental health.[16] Dance has been utilized as a form of therapy in patients with a variety of conditions, including Parkinson disease, dementia, and cerebral palsy. Dance has also been shown to increase functional mobility and have positive neurocognitive impacts. [4,11,13]

Dancers use certain muscles and bones more frequently than others to execute technical and artistic dance movements, which leads to a unique type of muscular development. The lower extremities and core are often most prominent in dancers since these body regions contribute to balance and stability.[20] Other musculoskeletal differences between dancers and non-dancers have been identified and have helped to explain why certain injuries are more common amongst dancers compared to athletes in other sports.[18]

Technical Analyses

The following paragraphs provide detailed analyses of the physiological implications of specific movements from my self-choreographed dance piece. The full video can be accessed using the link below, and time-stamped hyperlinks are provided throughout the text.

https://youtu.be/ETXdswwzu8c

Technical Analysis 1

The technical element executed at 0.19 requires extensive force and stability and is therefore dependent upon the coordination of a variety of muscular and skeletal elements. This movement, often referred to as a spring jump, first involves the firm placement of the dancer's hand on the floor. Dancers must widen their digits against the floor to maximize balance. One must also rely on the strength of the metacarpals and the bones of the wrist (scaphoid, lunate, triquetrum, pisiform, trapezium, trapezoid, capitate, hamate). Dancers can establish this position via brachioradialis contraction. The dancer's hand must also hyperextend via contraction of the extensor carpi radialis and extensor carpi ulnaris. The arm abducts, which is enabled by action of the deltoid and supraspinatus and opposed by action of the latissimus dorsi. The trapezius stabilizes the scapula in this position.

To execute a spring jump, the dancer must begin in a seated position, involving abduction of both thighs and flexion of both legs. This position involves the actions of the tensor fascia latae, iliopsoas, and adductor longus as well as the soleus and hamstrings group (biceps femoris, semimembranosus, semitendinosus). Next, the dancer must push against the floor and extend both legs, hyperextend the left thigh, and flex the right thigh. To propel the body off the ground, the dancer must utilize the right and left quadriceps femoris muscles as well as the gluteus maximus and hamstrings group.

Any injury to the muscles of the thigh can prevent proper execution of this technical element. Lower extremity injuries are common in dancers due to the high frequency of jumps and subsequent landings typical in this type of choreography. It was determined that for one 90-minute ballet or contemporary class, some dancers perform more than 150 jumps.[15] Jumps that involve landing on a single leg, such as the spring jump, require careful simultaneous contraction of both the quadriceps and hamstrings muscle groups, which enables the dancer to soften impact as they

reconnect with the floor. Additionally, this concurrent contraction allows joints, such as the knee, to become stiffened, thus increasing stability and enhancing injury prevention.[15] Research using electromyography has demonstrated that fatigue causes the ratio of quadriceps contraction to hamstrings contraction to increase. Thus, knee stabilization is compromised, increasing the likelihood of injury.[15] Therefore, proper development of both thigh muscle groups is essential to reduce the risk of jump-related injury in dancers.

Technical Analysis 2

Proper execution of à la seconde turns (0.42) depends upon the engagement of the muscles of the lower extremities and the abdominals. This technical element involves rotation upon a single leg. To maintain one's balance, dancers must contract the rectus abdominis. This contraction promotes a dancer's stability and prevents the body from falling forward or backward. Additionally, dancers must engage the internal intercostal muscles to avoid expansion of the ribcage, which can also lead to a loss of balance.

À la seconde turns involve the alternation between a single-legged plié and a single-legged elevé position. To execute the plié (a term that describes a position in which the knee is bent, and the thigh and leg are flexed), dancers must laterally rotate the thigh, involving contraction of the gluteus maximus and piriformis. Additionally, contraction of the biceps femoris enables flexion of the leg. Engagement of the quadriceps femoris muscles promotes flexion of the thigh and minimizes strain on the knee joint. While in this position, the dancer's heel lowers to the ground, prompting dorsiflexion of the foot. This involves contraction of the extensor digitorum longus and the tibialis anterior. This position also involves the extension of the Achilles tendon, which is crucial in the avoidance of future injuries. This tendon can be tightened via certain ballet

movements, particularly those performed en-pointe and demi-pointe—both of which are associated with plantar flexion of the foot.[19] This can lead to tendon degeneration due to improper tenocyte proliferation and impaired collagen production. This increases the risk of the development of Achilles tendinopathy, which is associated with pain and swelling of the tendon.[14] Therefore, it is imperative that dancers actively stretch this tendon as they execute technical movements. Consistent stretch of the Achilles tendon can promote synthesis of collagen and increased vascularity, thus reducing the likelihood of injury during à la seconde turns.[19]

The elevé position involves plantar flexion of the foot, and therefore requires contraction of the soleus, plantaris, and gastrocnemius. As the dancer lifts the heel from the floor, the knee joint also becomes straightened, thus extending the leg and the thigh. As the left lower extremity maintains contact with the floor and alternates between plié and elevé, the right leg remains extended and the right thigh remains flexed. The right thigh adducts as the left lower extremity is in plié, involving contraction of the adductor magnus and gracilis. The right thigh abducts as the left lower extremity is in elevé, which requires contraction of the gluteus maximus and gluteus minimus. The upper extremities alternate between rounded and extended positions and depend on contraction of the pectoralis major and biceps brachii as well as engagement of the triceps and trapezius.

Technical Analysis 3

The switch arabesque leap executed at 1.01 is an advanced technical skill which requires activation of multiple muscles of the lower extremities. Dancers prepare for this movement by executing a chassé (1.00) which accumulates momentum. Dancers must contract the quadriceps femoris muscles to flex both thighs. The biceps femoris muscles are also engaged to flex the leg.

The heel maintains contact with the floor, thus dorsiflexing the foot. Next, the dancers propel themselves upward while the lower extremities establish contact in the air. This involves the engagement of the hamstrings to extend the thigh and contraction of the quadriceps to extend the leg. The gracilis, adductor brevis, adductor longus, and adductor magnus contract to adduct the thighs while the gastrocnemius, soleus, and plantaris promote plantar flexion of the foot. The dancer then reestablishes contact with the floor and assumes the position involving flexed legs and thighs.

After the dancer completes the chassé, a single step is taken on the right lower extremity and preparation for the switch arabesque leap is complete. The dancer first hyperadducts the left lower extremity, involving engagement of the gracilis, adductor brevis, adductor longus, and adductor magnus. The thigh is also flexed in this position, enabled by contraction of the quadriceps muscles. The right lower extremity assumes a plié, involving flexion of the thigh and leg as well as dorsiflexion of the foot. Next, the left lower extremity engages in a complex series of fluid movements in which the thigh abducts and extends before subsequently flexing as the lower extremity relinquishes contact with the floor. The right lower extremity also loses connection with the floor as the thigh hyperextends. This is enabled by contraction of the biceps femoris, semimembranosus, semitendinosus, and gluteus maximus. While in this position, the triceps and trapezius muscles are engaged to promote extension of the upper extremities.

This movement places excessive pressure on the feet and ankles. Therefore, this technical element has potential to lead to the development of certain injuries. According to findings from a study which investigated ankle stability in dancers, it was determined that the strength of ankle muscles is often sacrificed for the sake of ankle flexibility.[8] Thus, it is imperative that dancers engage in ankle strengthening/stabilizing exercises concurrently with ankle stretching. Single- and

double-legged jumps in combination with exercises involving an elastic resistance band have been effective in improving ankle strength.[12]

Technical Analysis 4

While many technical elements in dance require great lower extremity strength and stability, others are more dependent on the upper extremities. This is evident in the movement occurring at 1.10. The lower limbs are strategically positioned for aesthetic purposes, but most of the strength required for the execution of this movement is generated by the upper limbs.

Both legs are flexed while the right thigh is hyperextended, and the left thigh is flexed. Engagement of the erector spinae enables the back to arch and the right foot to lift towards the dancer's head. The chest (manubrium, clavicle) and chin (mandible) establish contact with the floor. The forearms and wrists are flexed, involving contraction of the biceps brachii and brachialis, along with engagement of the palmaris longus, flexor carpi radialis, and flexor digitorum superficialis. The arms are also slightly abducted. Next, the dancer must propel the body backwards over the left knee while extending the right leg. This requires engagement of the pectoralis major to adduct the arms and flex them at the shoulder joint. Additionally, the forearms extend, involving action of the triceps brachii along with the extensor carpi radialis longus and brevis. After the forearms extend, the dancer establishes a seated position where both legs and thighs are flexed.

Some dancers may experience shoulder pain while executing such movement. Stretching of the pectoralis minor and upper trapezius have been shown to be effective in alleviating pain associated with overuse of the shoulder joint. Elastic resistance bands can be used to stretch and strengthen these muscles to facilitate the technical element described above. While exercise

therapy is thus a crucial factor in mitigating shoulder pain experienced by dancers, manual therapy has been shown to offer only minimal pain improvement in such situations.[3]

Technical Analysis 5

The technical element included at 1.42, a turning jeté with a back attitude, is often casually referred to as a "calypso." Dancers preparing to execute this movement complete a series of chaine turns. The first chaine turn involves plantar flexion of the feet and balance upon the sesamoids, and the second involves dorsiflexion of the feet, flexion of the thigh, and flexion of the leg to establish the plié position. During the chaine turns, the arms alternate between rounded and extended positions. To adopt the rounded position, the dancer must engage the biceps brachii and pectoralis major. Establishment of the extended position is enabled by contraction of the trapezius and triceps.

Next, the dancer must extend the right leg while flexing the right thigh, thus utilizing the quadriceps femoris muscles. Contraction of the gluteus maximus is also necessary for lateral rotation of the thigh while in this position. The left lower extremity maintains contact with the floor in plié as the thigh and leg are flexed and the foot is dorsiflexed. Next, the dancer pushes against the floor to propel upwards. The left lower extremity establishes a position known as "attitude." This involves hyperextension and lateral rotation of the thigh, flexion of the leg, and plantarflexion of the foot. Thus, this position's establishment depends on contraction of the hamstring muscles, gluteus maximus, and soleus. The back is hyperextended, and the chest is presented upward while the dancer's body is in the air. This involves engagement of the erector spinae, trapezius, and rhomboids to draw the scapulae towards each other.

Since this technical element involves use of the muscles of the back, dancers executing this movement may be at risk for spinal injury. Spinal injuries have been shown to be the second most common type of injury among dancers, with the most common being lower extremity injuries.[6] Spondylosis-associated back pain may be induced by extreme tightness of the hamstrings.[6] Therefore, proper stretching of these muscles is imperative for the prevention of injury in other areas of the body, including the spine. Sacroiliac joint sprain and lumbar facet sprain are also reported as common causes of back pain in dancers.[6] These injuries are exacerbated by dancers' frequent establishment of a "turned-out" position, associated with lateral rotation of each lower extremity. Treatment for such injuries include acetaminophen and NSAID consumption, manual therapy, and strengthening of the pelvic girdle.[6]

Discussion

Dance has been shown to have many positive impacts on physical and mental health. To demonstrate, one study found that subjects who participated in waltz and Greek genres of dance experienced more significant improvements in the relationship between maximal oxygen pulse/minute ventilation and carbon dioxide production when compared to subjects who participated in standard cardiovascular exercise.[5,9] Another study found that Zumba was a more effective intervention than soccer training at reducing serum glucose levels.[1,5] Dance has also been shown to prompt more drastic improvements in balance (measured via the Berg score), timed up-and-go tests, and sit-and-reach flexibility compared to other forms of structured exercise.[5] Moreover, a comprehensive analysis of several studies evaluating the effects of dance on a variety of biological markers has concluded that dance is more effective in reducing fat mass than cardiovascular exercise, soccer, jogging, and progressive resistance training. The

aforementioned finding has been shown to be true regardless of the sex and health status of the subjects.[5]

Dance (specifically aerobic dance on a mini trampoline) has been shown to positively impact bone formation, balance, and leg muscular strength.[2] Also, a study involving postmenopausal women demonstrated that dancing regularly can increase bone mineral density.[17]

Dance has also been evaluated as treatment for patients with neurodegenerative diseases. One study analyzed the effects of dance versus exercise of the same intensity in subjects with mild dementia. It was demonstrated that dance leads to decreases in loneliness and depression as well as improvements in mood, diurnal cortisol slope, and overall daily functioning in patients.[7] In addition, dance has been shown to improve dexterity and functional mobility in patients with Parkinson disease.[10] Thus, dance can produce positive changes in physiological health indicators in a variety of populations.

The knowledge I have obtained throughout my undergraduate education has been crucial amidst my prevention of dance-related injuries. Therefore, I am confident that many dancers would benefit by establishing a foundational understanding of musculoskeletal physiology. More specifically, educating dancers on these concepts early in their careers can ensure that proper muscular development occurs. Moreover, dance and physiology are deeply intertwined and concurrent investigation of these two disciplines is extraordinarily valuable.

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