Applying Biomechanic Research in the Dance Studio

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The training of dancers is both an aesthetic and scientific pursuit. Dance teachers train their students to develop both artistry and skill, relying on their innate understanding of the body moving through space. Biomechanists identify and quantify elements of human movement, focusing on the mechanical principles of a particular skill. Whereas dance training is characterized by a systematic progression of repeated motions, biomechanics observes forces acting on the body, which contributes to an understanding of the technical demands and artistry of dance. The goal of this article is to show how biomechanics can enhance and augment an understanding of dance training.

In a biomechanical perspective the body is observed as segments linked at the joints; these joints and joint motions are the building blocks for analysis. Biomechanics looks at measureable aspects of movement (such as speed and force), and it can define and describe elements of skilled action. Biomechanical analysis of movement requires the use of specific measurement tools which are employed to describe muscular activity, understand forces acting on the body, observe movement of the center of mass, and examine movement either in the whole body or individual segments. Biomechanic research is conducted in a laboratory, wherein the movement is measured in accordance with specific guidelines; however, information obtained from biomechanical analysis can be used to clarify and enhance the teaching of dance and dance performance. An emerging subsection of biomechanics, dance biomechanics, looks specifically at the complex movements of dance, with the goal of understanding the mechanical principles for the enhancement of training and performance.

The goal of this paper is to demonstrate how information gained from research in biomechanics can be useful in the dance studio. Each of the following sections focuses on a particular dance movement. The skill is introduced with a general research question, a brief summary of pertinent research is provided, and the section concludes with information directly related to teaching.

Grand Plié: Balancing Range of Motion with Strength

Grand plié is a vital part of most dance technique classes. In a movement such as grand plié, where the range of motion and physical exertion is of sufficient difficulty, looking at the movement "from the inside out" sheds light on how it should be taught. Biomechanists and dance teachers have been studying the grand plié for a long time, trying to understand how to optimize the benefits of this movement while minimizing the potential risks to the knee. Grand plié is used in a dance class to strengthen the legs and to warm up the hips, knees, and ankles. However, the extreme flexion of the knee required in this movement is something that requires proper coaching for safe execution. Trepman and colleagues, using electromyographic analysis (where surface electrodes monitor electrical activity in the muscles), found that performing grand plié at the barre reduces stress at the knee, while doing the movement without the barre requires greater quadriceps strength.[1] For modern dancers, in particular, learning grand plié at the barre is an important recommendation. Barnes recommends incorporating grand plié at the end of the barre section of class rather than at the beginning, to maximize the benefits of the movement and to diminish the potential for incorrect execution.[2] With the muscles properly warmed, the benefits of grand plié are more fully realized.

Grand plié is important for strengthening the legs and increasing the range of motion of the lower body, and is most effectively practiced when the body is "warm." As a recommendation to the teacher, the barre should be used for practice of this movement until sufficient strength is attained, and placing the grand plié at the end of the barre will maximize the benefits available from this movement.

Développé Devant: Developing Strength in the Gesturing and Standing Legs

Many dance movements are practiced at the barre to help the dancer develop focus and strength without balance concerns. Dance biomechanists are interested in how working at the barre increases strength in the moving or gesture leg and in the supporting or standing leg. Using electromyography, Wilmerding identified different muscular responses in the supporting leg for développé devant at the barre and in center floor work. She noted that use of the barre helped the dancer address action in the gesture leg, but did not provide sufficient stimulus to develop the supporting leg musculature.[3] In other words, the barre replaces some of the work of the standing leg. Strengthening of the standing leg is augmented when working in the center. As a recommendation to the teacher, this research confirms the importance of repeating movements learned at the barre in the center for training both the gesture and standing legs.

Jumping: Understanding Forces Acting on the Knee, And Contribution of the Upper Body

Dancers move through space vertically and horizontally, jumping both for height and to travel through space. Dance biomechanists are interested in the forces acting on the knee in jumping. When jumping straight up and down (sauté in first position) dancers are incurring a force that is anywhere from three to five times their body weight. With jumps that travel through space, such as grand jeté, the dancer is also incurring a horizontal force upon landing. There is a "braking" action in the anterior thigh muscles (quadriceps group) that creates a shearing force at the ankle and knee. This force occurs between the upper and lower leg, as they are moving in different directions, with the greatest force seen at the muscles and soft-tissue of the knee. Simpson and colleagues note that excessive use of the quadriceps muscle group relative to underutilized hamstring muscles creates an atypical force in landing from a forward moving jump.[4] Strengthening the hamstring muscles is an important way to improve the jumps and limit overuse of the quadriceps. This is extremely important for maximizing power and minimizing unbalanced strain. A simple way to strengthen the hamstrings is to have a dancer move from a parallel tendu back to parallel attitude, flexing the knee against gravity or a mild resistance.

Beyond the issue of strength and muscle recruitment of the leg muscles, additional focus on the action of the whole body is an important consideration in jumping. Poggini and associates looked at young novice dancers and noted the need for additional training to help them maintain proper body position in the air.[5] Specifically, dancers need to control movement of the head, shoulders and hips in both the take-off and landing from the jump, keeping the body from buckling forward or arching back. Understanding that jumping is a whole body motion refocuses our thinking on training for this dynamic movement.

As a recommendation to the teacher, these studies point out the need to find ways to balance the work in the leg by strengthening the hamstring muscles, and improve the aesthetic quality of jumping by focusing on the position of the whole body.

Grand Rond De Jambe En L'air: Understanding Segment and Joint Motions

Most dance movement can be categorized as one or two body parts moving in relation to, and supported by, the rest of the body. The movement of one segment has an effect on the rest of the body, as well as the movement as a whole. Dance biomechanists have been interested in how this interaction is seen in movements with a full range of motion in the spine, such as grand rond de jambe en l'air.

Wilson and coworkers, looking at the interaction between the gesture leg and pelvis, found that skilled dancers had greater range of motion in the pelvis accompanying the range of motion for the gesturing leg. In other words, after the leg has reached a certain height the pelvis *must* move to accommodate further range of motion. Movements to the front and side (devant and à la seconde) past 90 degrees of flexion involve the pelvis in three-dimensional movement. To the back, anterior tilting of the pelvis is seen after 15 degrees of hip hyperextension (arabesque). This research clarifies the role of the pelvis in movements at the hip joint that require large ranges of motion. To move the leg fully the pelvis must follow the leg, even though the illusion advocated is to keep the pelvis immobile.[6]

A follow-up study investigated the role of the pelvis in facilitating gesture leg motion, and the related "cost" of the muscles involved.[7] For skilled dancers the effort in the gesture leg is smaller than in the standing leg. This was reversed in less skilled dancers. The investigators concluded that the skilled dancers are working more efficiently in their standing leg to support the pelvis and gesture leg, whereas the less skilled dancers are mostly using the muscles in the gesturing leg.[7]

A recommendation to the teacher: when working on movements where one leg is moving fully, a strategy to focus on the standing leg will help balance the necessary movement in the pelvis and spine. Not allowing the pelvis to move commensurately with the gesturing leg will decrease the potential range of motion and place unnecessary stress on the hip joint and lumbar spine.

Balance and Practice: Understanding Vertical Orientation and Variability in Performance

Dance researchers have an interest in strategies that dancers use for balance, and what variability in movement skill is telling us about learning and performance. Strategies that dancers use for balance and counterbalance are based on neuronal and reflex adjustments that develop with dance training. Mouchnino and colleagues found that dancers use a (subconscious) motor program to maintain the vertical orientation of the head when the leg is moving. They accomplish this by counter-rotating in the trunk, and by moving the spine and pelvis around the hip joint to keep the body vertical. This helps dancers maintain the vertical

line that is often desired in ballet.[8] In addition, Monasterio and colleagues found that postural adjustments precede voluntary leg movements. The systematic training that dancers receive actually re-programs many motor patterns involved in balance and limb control.[9] As demonstrated by Monasterio and colleagues' research, the admonition that dance teachers give to their students to "move from the core" is clearly valid.

Although issues of motor control may not be at the forefront of pedagogical discussions, understanding the neural underpinnings of movement helps to clarify our analysis and teaching of movement. One of these concepts has to do with muscle recruitment patterns. Electromyography (EMG) documents patterns of muscular recruitment that illuminate an individual dancer's strategy for performing movement. These patterns of muscle recruitment often demonstrate variability between dancers performing the same action. In fact, data collected in many studies using EMG data have shown variability between subjects. Chatfield notes that even for a highly skilled performer no two performances are exactly the same. Observing multiple trials for the same individual over time generates information regarding neuromuscular activity that can be combined to understand the consistency and variability in the performance.[10] Consistency is a measure of learning, whereas variability shows that there are fluctuations in neural and muscular timing for any given movement.

These articles identify two very important concepts. First, training the dancers to maintain a vertical orientation in the trunk and head develops important neuromuscular patterns that are integral for balance. Second, variability is a useful measure of learning and performance. A recommendation to the teacher is to understand that in order to develop the correct neuromuscular patterns in class, consistency (doing movement the same way every time) and variability (doing it in a different tempo or combination) are both important to development of a specific skill.

Summary and Conclusion

Employing technology to augment the trained eye of the teacher and the innate understanding that dancers have of their own bodies, biomechanical analysis has illuminated many intricacies of specific movements often invisible in the real-time execution of the movement. Without reducing skill to a numerical formula or graphed pattern, expert performance can clearly be seen and described using biomechanical tools. Both quantitative and descriptive information are generated that provide rich detail of a given movement. This is relevant to teaching, as it not only validates but clarifies what we do in the dance studio for the betterment of the training of dancers and the future of performance.

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