4-20-2018

Comparative Analysis of Impact of Ballistic Stretching and Dynamic Stretching on Power Output in Female Collegiate Dancers

Elisabeth Ohrnberger
Western Michigan University, eaohrnberger@gmail.com

Comparative Analysis of the Impact of Dynamic and Ballistic Stretching on Power Output in Female Collegiate Dancers

Elisabeth Ohrnberger

Thesis Committee: Dr. Nicholas Hanson, Dr. Sangwoo Lee, Dr. Debra Berkey

Western Michigan University

May, 2018

Abstract

The purpose of this study was to examine two different stretching techniques, ballistic and dynamic, and observe their effects on power output, measured via vertical jump height and vertical ground reaction force (vGRF). In the past, there has been insufficient and conflicting research regarding the type of stretching on power output. Stretching has been used in athletics to increase flexibility, prevent injury, and increase overall athletic performance. However, there is little research specifically demonstrating whether stretching has the ability to prevent injury or improve performance. Dance skills require significantly more flexibility than other sports while still requiring power to complete jumps and leaps.

This study specifically recruited female collegiate dancers. An experimental design was used where each participant completed two lab sessions. During each session, the participant completed either the ballistic or dynamic stretching protocol and then performed five vertical jumps. By completing the jumps on a force plate, the vGRF force was calculated. The height of the jumps was measured and recorded by retro-reflective markers placed on the lower extremities, which were recognized and recorded by a real-time motion capture system. Using the information from the force plate and the real-time motion capture system, jump height and vGRF force generated were calculated. The data was analyzed using Kwon3D Motion Analysis Suite and SPSS was used to calculate statistics on the data collected.

Introduction

The purpose of completing a warm up and/or stretching is to prepare the body for upcoming demands of workouts or team practices. There are several different types of stretching techniques, each having their own advantages and disadvantages. For example, ballistic stretching can be used to maintain flexibility but can be more likely to cause injury (Prentice, 2014, p. 115).

Ballistic stretching is defined as "rapid lengthening of the muscle by use of jerking or bouncing movements" (Thacker, Gilchrist, Stroup & Dexter Kimsey, 2003, p. 372). One purpose of ballistic stretching is to activate the musculotendinous unit and stretch reflex allowing for the muscle to become stretched further during activity and increase force absorption (Scifers, 2011, p. 88). A variety of studies using dancers as their population found ballistic stretching to be effective at increasing flexibility (Deighan, 2005, p. 13; Prentice, 2014, p. 115). This type of stretching technique is more commonly seen in sports that demand a larger range of motion such as dance and gymnastics.

Dynamic stretching has been defined as "the movement of the limb through a range of motion by contraction of agonist muscles in a slow-deliberate motion" (Brandy, Irion, & Briggler, 1998, p. 296). Dynamic stretching utilizes sport specific movements that move through the entire functional range of motion of pertinent muscles (Mann & Jones, 1999, p. 53). The unique rationale supporting dynamic stretching is how it maintains the integrity of the musculotendinous unit stiffness in order to maximize force production (Yamaguchi & Ishii, 2005, p. 682). This benefit is why dynamic stretching is commonly seen in sports such as football, track and field, and basketball that contain power-based, explosive movements.

Power is the ability to generate muscular force quickly and is necessary for movements like jumps. (Hall, 2012, p. 165). Jump height and vertical ground reaction force (vGRF) are often measured as a correlate of power output due to the variables' direct relationship with power. This is shown in biomechanics software as vGRF and also as the change in the position of the retroreflective markers, from standing to maximum jump height.

Background Information

Stretching is defined as "any therapeutic maneuver designed to increase soft tissue" mobility (Scifers, 2011, p. 81). Stretching is important due to the length-tension curve that describes the relationship of the length of a muscle and its amount of force or tension produced (Scifers, 2011, p. 83). Muscles can be shortened or overstretched which could change the resting tension of the muscle – either of which could cause a decrease in force production to occur as seen in the length-tension relationship of muscle (Hall, 2012, p. 160). Muscles generate the greatest force production at the midpoint length of the muscle with a slight stretch applied (Hall, 2012, p. 160; Scifers, 2011, p. 83).

To facilitate a stretch, the agonist muscle group contracts. Simultaneously the antagonists, the opposing muscle group, lengthens and becomes stretched (Scifers, 2011, p. 83). Reciprocal inhibition is the concept of the contraction of the agonist causes reflexive relaxation and the ability to stretch the antagonist muscle (Scifers, 2011, p. 87). The musculotendinous unit is a group of muscles and tendons (Starkey & Brown, 2015, p. 75). Within the body of the antagonist muscle, near the musculotendinous unit, the stretch reflex occurs. The stretch reflex is created by two mechanoreceptors, golgi tendon organs (GTO) and muscle spindles, that measure the changes of muscle length and create the neurophysiological stretch reflex (Prentice, 2014, p. 114).

The GTO is a mechanoreceptor, created by a bundle of collagen fibers, located near the musculotendinous junction, that attaches to its adjacent muscle fibers and nerve endings that are innervated by a single axon (Tierney et al., 2011, p. 276). As a mechanoreceptor, the GTO's purpose is to monitor muscle tension or the force production occurring in the muscles. As a muscle contracts, the collagen within the GTO becomes stretched and the nerve endings become compressed, resulting in signals firing to the spinal cord (Tierney et al., 2011, p. 276).

A muscle spindle is also a mechanoreceptor located within the extrafusal muscle (Tierney et al., 2011, p. 276) and composed of two distinct components. One component of muscle spindles is the intrafusal fibers that contain noncontractile centers and lie parallel to the extrafusal muscle fibers (Tierney et al., 2011, p. 276). The second component is sensory fibers that begin at the noncontractile center of the intrafusal fibers and contain motor neuron endings that innervate the endings of the contractile intrafusal fibers (Tierney et al, 2011, p. 276). The purpose of the muscle spindle is to monitor and send signals to the spinal cord regarding the rate of muscle length change (Tierney et al., 2011, p. 276-277). The signal is sent to the spinal cord when the intrafusal fibers and the sensory endings are stretched – causing the muscle spindle to become "loaded" and increase the firing rate of the signals (Tierney et al., 2011, p. 276).

The stretch reflex occurs when both the GTO and muscle spindles are stretched by the adjacent muscles. The combination of these signals regarding the length and tension within a muscle travel to the spinal cord generating the stretch reflex, autogenic inhibition and reciprocal inhibition. (Scifers, 2011, p. 86). After the stretch has been applied for eight seconds, the GTO sends a message that overrides the signal from the muscle spindle, monosynaptic stretch reflex contraction, resulting in the relaxation on the antagonist muscle and increasing the stretch – called autogenic inhibition (Scifers, 2011, p. 87). Reciprocal inhibition also occurs when the agonist muscle contracts, causing a reflexive relaxation of the antagonist muscle (Scifers, 2011, p. 86). The end result of the reciprocal inhibition is increased firing of the GTO while decreasing the overall muscle tension (Scifers, 2011, p. 87).

Ballistic stretching is an older stretching technique (Prentice, 2014, p. 115) that includes exercises performed at high velocities that have the athlete move through greater dynamic flexibility, seen as bouncing or pulling and jerking movements (Prentice, 2014, p. 115; Scifers, 2011, p. 92). Since higher velocity is used during the exercises, there is an increased chance for exceeding the capacities of the tissue to elongate. If the tissue can no longer lengthen, it will fail or tear (Prentice, 2014, p. 115). The monosynaptic reflex seen in ballistic stretching is created from the afferent signals that originate from the muscle spindle and travel to the ventral horn of the spinal cord (Scifers, 2011, p. 88). The result of the signal from the muscle spindle is the monosynaptic stretch reflex contraction, which causes the muscles to shorten and limit the elongation impact of the stretch (Scifers, 2011, p. 88). The monosynaptic stretch reflex contraction helps decrease the risk of failure of the tissue during the stretch (Scifers, 2011, p. 88). While performing ballistic stretching, there is a risk of muscle soreness which is why it is not currently a common recommendation (Prentice, 2014, p. 117). However, the same risk is possible with dynamic stretching.

Dynamic stretching is a variation of ballistic stretching which focuses on exercises that move through the athlete's normal active range of motion, or dynamic flexibility, in a controlled manner (Prentice, 2014, p. 116; Scifers, 2011, p. 92). Dynamic stretching has become the most commonly used type of stretching technique before activity due to the activity specific nature of the progression of the exercises or stretches (Prentice, 2014, p.

116; Scifers, 2011, p. 92). Dynamic stretching also causes a significant increase in blood flow to the targeted tissues of the warm up and it is recommended to be used before large force production types of activities (Scifers, 2011, p. 92-93). Compared to ballistic stretching, dynamic stretching is safer because it is meant to stay within the athlete's dynamic flexibility and performed at a lesser velocity therefore decreasing the risk of injury or muscle soreness (Prentice, 2014, p. 116). However, if dynamic stretching is performed incorrectly or repetitively overused, it could cause muscle soreness (Prentice, 2014, p. 117).

Purpose

The purpose of this study was to examine the potential effects of two stretching techniques, ballistic and dynamic, on power output via vertical jump height.

Methods and Materials

Subject Recruitment

Recruitment focused on Western Michigan University (WMU) female dance majors and minors between the ages of 18 and 30 years old. Recruitment emails were sent to potential participants from dance department faculty. Flyers were distributed in the fine arts building on WMU's campus. All participants signed an informed consent document before any data was collected. To determine if participants were classified as medically low risk, the Physical Activity Readiness Questionnaire (PARQ) medical questionnaire was administered. All participants were classified as low risk before completing data collection for the study. A total of five subjects were recruited (n=5). The average age of the participants was 18.8 years +/- 0.4 years. The mean height and mass were 167.8 cm +/- 4.3 cm and 59.8 kg +/- 2.4 kg respectively.

Methods of Data Collection

There were two required lab visits to complete the study. The participant performed one of the stretching technique protocols and then the other stretching protocol in the following lab visit. For both sessions, the participant began with a five-minute warm up on a treadmill at a self-selected speed. Following the warm-up, retro-reflective markers were placed on pre-determined, standardized anatomical sites. Afterwards, each participant either completed the ballistic or dynamic stretching protocol. The protocol order given to the participants was randomly assigned.

The ballistic stretching protocol included three movements that were completed for 30 seconds, at a tempo of one beat per minute. The movements included were: standing quadriceps stretch (repeated on both sides), good mornings, and calf raises. Good mornings are described as the participant placing their arms on the back of their head with a stance slightly wider than shoulder width. The participant then bends at the hip while keeping the back straight until stretch is felt in the hamstrings. After 30 seconds, the participant then stands back up straight and repeats exercise. These movements were selected because the quadriceps, hamstring, and gastrocnemius are key muscle groups involved in vertical jump height.

Figure 1. Ballistic stretching protocol, standing quadriceps stretch.

Figure 2. Ballistic stretching protocol, good mornings.

Figure 1. Ballistic stretching protocol, calf raises.

The dynamic warm up protocol included three movements that were completed across 10 meters. The movements included were: high knees, butt kickers, and tip toe (or ballerina) walks. The pace to complete the movements was a fast pace but not specifically set to a tempo or timed. These movements were selected because they also focused on the same muscles as the ballistic stretching technique - quadriceps, hamstring, and gastrocnemius.

Figure 4. Dynamic stretching protocol, butt kickers.

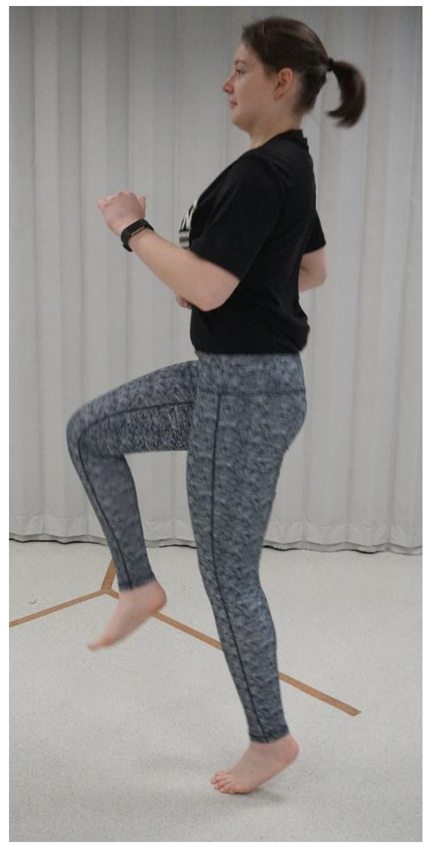

Figure 5. Dynamic stretching protocol, high knees.

Figure 2. Dynamic stretching protocol, tip toe walks.

Table 1. To summarize and directly compare the two different stretching techniques used

Ballistic Stretching	**Dynamic Stretching**
60 bpm, 30 seconds per movement	10 meters per movement
Movements Used:	Movements Used:
Quadriceps Stretch	High Knees
Good Mornings	Butt Kickers
Calf Raises	Tip Toe Walks

Once either protocol was completed, the markers on the foot and ankle were placed on pre-determined anatomical markers for the Real-Time Motion Capture System (Vicon, CO, USA), totaling 19 markers. The foot and ankle markers were not placed on the participants before the stretching protocol was completed due to the tendency of makers falling off during the protocol. The anatomical sites for the markers were: right and left anterior superior iliac spines (ASIS), right and left posterior superior iliac spines (PSIS), sacrum, right and left iliac crests, right and left greater trochanters, right and left lateral aspect of mid-thigh, right and left lateral knee, right and left medial knee, right and left lateral shank, right and left lateral malleoli, right and left medial malleoli, right and left heels, right and left first or great toes. The estimated amount of time to place the markers on the participant was between 30 and 45 seconds. The participant then executed five vertical jump trials on the force plate (Advanced Mechanical Technology Inc., MA, USA) with 30 seconds of rest in between each trial. During the jumps, the participant did not have the right and left medial knee, or the right and left medial malleoli reflective markers due to likelihood of falling off during the testing. After data from the jumps were collected, the bilateral medial knee and medial malleoli markers were placed on the body to collect further position information for the camera system, with 23 markers on the lower extremities of the participant.

The retro-reflective markers were used to document the participant's jump height. The force plate recorded the vGRF generated by the participant during their jumps. The Kwon3D Motion Analysis Suite (Visol Inc., Seoul, Korea) was used to compute the data collected and biomechanical variables. From the Kwon3D, the data was pulled and run through SPSS (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) for paired sample t-tests as statistical analysis.

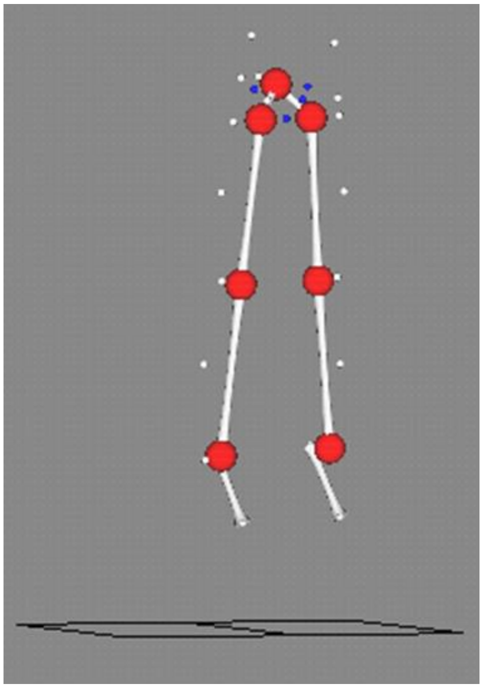

Figure 7. Participant in mid jump with retro-reflective markers on.

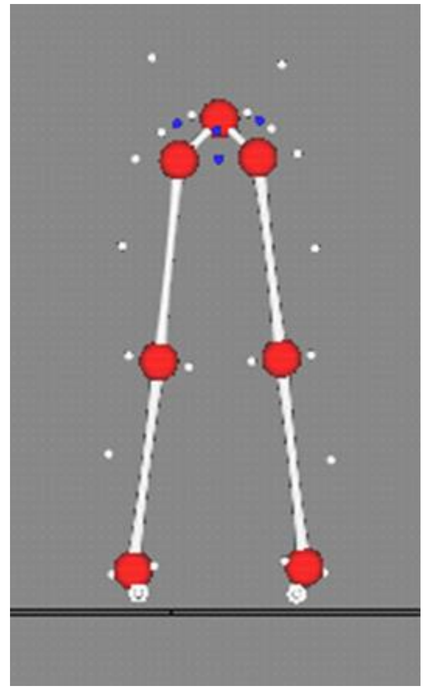

Figure 8. Participant with all 23 retro-reflective markers used for data collection.

Results

With these readings, as seen in Table 2, one can determine that there is no significant difference in jump heights or ground reaction forces generated when comparing ballistic and dynamic stretching techniques. Therefore, there is not a significant difference in power output generated when comparing the two stretching techniques.

Table 2. Comparison of the stretching protocols and data collected with statistical analysis

	Ballistic Stretching	Dynamic Stretching	P value	T value
Jump height (m)	0.40 +/- 0.05	0.40 +/- 0.05	0.698	0.417
vGRF (N/kg)	24.35 +/- 2.77	24.26 +/- 1.99	0.822	0.241

Discussion

The main finding from this pilot study was that there is no significant difference for several reasons. Since dynamic stretching and ballistic stretching are very similar, there may not have been a great enough distinction between the two stretching techniques and how they affect muscles differently. Dance movements are vastly different than traditional athletic movements like running and jumping. Therefore, insignificant results may have been found because dancers are not used to performing traditional athletic movements like vertical jump for height. If jumping is a finite ability, there may have been insignificant results because the participants could have not had the ability to jump any higher.

A specific limitation of this study is the small sample size which made it difficult to run analysis and compare statistics to find significant differences. Due to the convenience sampling, there might be a lack of generalizability to other sports and the general population. A potential change to consider for the study, would be to have the participants perform dance specific jumps rather than vertical jumps. In the future, measuring the impact of the different stretching techniques on flexibility should be analyzed. Furthermore, the length of time of the stretch should be reviewed for both dynamic and ballistic stretching to find the relationship to flexibility, jump height, and vGRF force.

Conclusion

The purpose of this study was to examine two different stretching techniques, ballistic and dynamic, and observe their effects on power output via vertical jump height and vGRF force. The results of the experiment demonstrated that there was not a significant difference in power output measured via vertical jump height or vGRF while comparing ballistic and dynamic stretching. To confirm these findings, there should be further research completed in the future.

Dalrymple, Davis, Dawyer, and Moir had similar results and found there were not significant differences in peak jump height when comparing dynamic, static, and no stretching conditions (2010, p. 153). Despite the lack of statistically significant findings while analyzing the data of all participants, several individual subjects produced greater peak jump heights with dynamic stretching compared to static stretching or no stretching conditions (Dalrymple et al., 2010, p. 153). Dalrymple et al. (2010) also investigated the potential effects of time lapsing between the application of stretch and exercise performed - which still needs to be investigated further. Kirmizigil, Ozcaldiran, and Colakoglu found that stretching techniques coupled together can change the effect on the participant's vertical jump performance (2014, p. 1268). Ballistic stretching when paired with proprioceptive neuromuscular facilitation (PNF) caused an increased vertical jump height. However, when ballistic stretching was solely utilized there was more of a significant increase in vertical jump height compared to the PNF and ballistic stretching paired intervention (Kirmizigil, Ozcaldiran, & Colakoglu, 2014).

Samuel, Holcomb, Guadagnoli, Rubley, and Wallmann found very different results. Samuel et al. compared ballistic and static stretching in male and female participants while observing the effect on vertical jump height, hamstring torque, and quadriceps torque (2008, p. 1425). The results yielded no significant differences between ballistic and static stretching for any of their variables (Samuel et al., 2008, p. 1425). Additionally, Samuel et al. did not find any significant differences due to gender of the participant (2008, 1425). The differing results between Dalrymple et al. (2010) and Samuel et al. (2008) demonstrates the need of further investigation on the effects of different stretching techniques on varying athletes of both genders.

References

Brandy, W. D., Irion, J. M., & Briggler, M. (1998). The effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles. *Journal of Orthopaedic & Sports Physical Therapy, 27*(4), 295-300.

Dalrymple, K. J., Davis, S. E., Dwyer, G. B., & Moir, G. L. (2010, January). Effect of static and dynamic stretching on vertical jump performance in collegiate women volleyball players. *Journal fo Strength and Conditioning Research, 24*(1), 149-155.

Deighan, M. A. (2005). Flexibility in dance. *Journal of Dance Medicine & Science, 9*(1), 13-17.

Hall, S. (2012). *Basic Biomechanics* (7th ed.). New York, NY: McGraw-Hill.

Kirmizigil, B., Ozcaldiran, B., & Colakoglu, M. (2014, May). Effects of three different stretching techniques on vertical jumping performance. *Journal of Strength and Conditioning Research, 28*(5), 1263-1271.

Mann, P., & Jones, M. (1999). Guidelines to the implementation of dynamic stretching program. *National Strengthening and Conditioning Association, 21*(6), 53-55.

Prentice, W. E. (2014). *Principles of Athletic Training.* New York: McGraw-Hill Companies.

Samuel, M. N., Holcomb, W. R., Guadagnoli, M. A., Rubley, M. D., & Wallmann, H. (2008, September). Acute effects of static and ballistic stretching on measures of strength and power. *Journal of Strength and Conditioning Research, 22*(5), 1422-1428.

Scifers, J. R. (2011). Stretching. In M. Higgins, *Therapeutic Exercise: From Theory to Practice* (p. 79-103). Philadelpha: F. A. Davis Company.

Starkey, C., & Brown, S. D. (2015). *Examination of Orthopedic and Athletic Injuries.* Philadelphia: F. A. David Company.

Thacker, S. B., Gilchrist, J., Stroup, D. F., & Dexter Kimsey, Jr, C. (2003). The impact of stretching on sports injury risk: A systemic review of the literature. *Journal of the American College of Sports Medicine, 36*(3), 371-378. doi:10.1249/.01

Tierney, R. T., Driban, J. B., & Scifers, J. R. (2011). Proprioception. In M. Higgins, *Therapeutic Exercise: From Theory to Practice* (p. 273-288). Philadelphia, PA: F. A. Davis Company.

Yamaguchi, T., & Ishii, K. (2005). Effects of static stretching for 30 seconds and dynamic stretching on leg extension power. *Journal of Strength and Conditioning, 19*(3), 677-683.