Responsive Kinetic Training Positively Increases Knee Joint Stability

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By
Bryonne Herring
Kinesiology Major & Biology Minor

The College at Brockport
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Thesis Director: Dr. Christopher Williams, Associate Professor
Department of Kinesiology, Sport Studies, and Physical Education

Abstract

Neuromuscular adaptations are primarily responsible for more explosive movements through recruitment of fast twitch muscle fibers; and as a result, rate of force development increases, which may increase joint stability. The purpose of this study was to determine the effects of neuromuscular training on joint stability. Using the Ariel Computerized Exercise System (ACES), a 4-week training program was developed. Ten participants performed squats, leg drives, lateral squats, and deadlifts twice a week, for three sets of ten seconds each, at 50% of maximal velocity. Pre and post-tests were performed using the Landing Error Scoring System in Real Time (LESS-RT). Results indicated significant decrease in scores, indicating that the risk of injury had decreased and joint stability increased.

Introduction

In strength and conditioning, there are many methods used that are believed to be best for improving performance on the neuromuscular level. To do so, methods aimed at neuromuscular adaptations typically require maximal effort intensity. In doing so, adaptations occur in the central and peripheral nervous systems, the neuromuscular junction, and the muscle itself. And these neuromuscular adaptations will ultimately increase performance, joint stability, and decrease the risk of injury.

Central Nervous System Adaptations

In order for maximal intensity training adaptations to occur, the first step must occur in the central nervous system (CNS). This process is described as an increase in neural drive. Through the cortex of the brain, neural drive is increased, and the spinal cord begins to see significant neural changes down the corticospinal tracts.[4,11,17] Increasing neural drive will result in an increase of the agonist muscle recruitment of fast twitch fibers, a decrease in the antagonist muscle activation, and proprioceptive inhibition. The level of neural drive directly affects the amount of muscle force production, and therefore can be used to manipulate maximal intensity training.[21,22,23]

Muscle fibers are grouped into motor units – a single motor neuron and the muscle fibers it innervates. Within a motor unit, muscle fibers are known to have the same characteristics (e.g. slow or fast twitch). Fast twitch motor units are more explosive, quicker to fatigue, and have a high activation threshold (e.g. type IIa and IIx). Slow twitch motor units are less explosive, slower to fatigue, and have a low activation threshold (e.g. type I).

The level of motor unit recruitment is dependent on the size principle.[21,22,23] The size principle states that slow twitch fibers will be recruited first, followed by the fast twitch fibers. When the fast twitch fibers need to be recruited, all of the lower fibers are recruited sequentially. Depending on the intensity of the load, the number of motor units recruited may vary. However, training at a maximal muscular intensity and speed enables the CNS to bypass the size principle and selectively recruit fast twitch fibers. Even though all fibers adapt through heavy resistance training, the fast twitch fibers are recruited last. And by training with a heavy load, slow twitch fibers will adapt (hypertrophy), although they are (a) not fast enough to contribute to a high-speed movement, and (b) will act as resistance to high speed movements because they must be compressed within the muscle during high speed contractions.

In high intensity training, selective recruitment by the CNS will recruit higher threshold motor units first to attempt to provide a greater production of force.[12] Because of this, fast twitch motor units are recruited and the slow twitch motor units are inhibited. Furthermore, the recruitment of fast twitch, high threshold motor units reduces the required activation needed for subsequent recruitment. As a result, selective recruitment allows for higher threshold motor units being activated during recruitment.[13]

Neuromuscular Junction and its Adaptations

The neuromuscular junction (NMJ) is the connection between a motor neuron and the skeletal muscle. Studies in animals have shown that high intensity training can increase the area of the NMJ, as well as increase the dispersion and sensitivity of acetylcholine receptors at the end plate portion. High intensity training produces changes in the NMJ that produces a positive change in neural transmission from the motor neuron to the muscle fiber.[7,8,9,10] With enhanced neural transmissions, the recruitment of higher fibers is increased.

Adaptations to the Muscle

Muscle fiber type resides on a continuum through a number of factors such as, contractile force, relaxation time, contraction time, and oxidative capacity. The continuum relies greatly on myosin heavy chain expression.[12] Generally, fiber type proportions in each individual are predetermined through genetics. However, it is thought that these fibers may change in response to high intensity training.[20]

Furthermore, the activation of the higher threshold motor units with higher intensity training has been linked to adenosine triphosphatase (ATPase) isoform content.[14] Currently, there is evidence to suggest that fiber type transitions occur only within fast twitch fiber sub types (e.g. type IIa and IIx). There is less evidence indicating transitions from slow to fast twitch fibers; however, there is insufficient evidence to disprove that the transition is, in fact, impossible.[20]

Neuromuscular Control, Proprioception, and Reflex Potentiation Adaptations

Neuromuscular control for moving the body relies on the combination of both the central nervous system (CNS) and the peripheral nervous system (PNS), as well as the senses of the body.[16] As a result, an individual playing basketball, for example, will use both conscious movement strategies as well as proprioception.[15] For the neuromuscular system, neuromuscular control comes from afferent sensory information sent to the CNS. When an individual begins to move voluntarily, efferent motor neurons are used to send impulses down the descending corticospinal tracts to muscle fibers. Efferent neurons also innervate proprioceptive and kinesthetic organs. As a result, with increased neural drive, enhanced muscle stiffness and improved proprioceptive sensitivity results in reduced latency of muscle force application. [6,15,16]

Rate of Force Development, Power, and Joint Stability

An expected adaptation from high intensity training is the ability for someone to produce greater force in less time. This is known as rate of force development (RFD). RFD is defined as the slope of the force-time curve and determines the force that can be generated in the beginning phases of muscle contraction. [1] RFD can be increased with increased neural drive, increased neural transmission efficiency, greater recruitment of fast twitch fibers, and decreased muscle latency. And RFD provides a starting point for a number of expected outcomes in performance.

When it comes to making fast explosive actions, RFD is much more important than muscular strength.[2,6] It takes a muscle 300ms to voluntarily contract to its peak.[2] However, explosive movements in sport take a muscle between 50-250ms. On the other hand, non-contact ACL injury occurs within 70ms after ground contact.[2,7] To better stabilize the knee joint, strengthening the musculature and increasing muscular responsiveness that surrounds the knee will decrease the risk of ACL injuries.[6] Therefore, the greater the force from the muscles within 70ms (e.g., RFD) at the knee, the more stable the knee will be. And the more stable the knee, the less likely there is for an injury to occur.

Because maximal muscle force does not occur fast enough, maximal strength is not the most important factor in sports regarding joint stability. And as a result, RFD not only creates explosive power leading to greater athletic success, but also has more importance on joint stability and injury prevention.

Purpose of Study

Increasing RFD is important for athletic performance as well as preventing injuries. and the same strategies used to prevent injuries for athletes can also reduce injuries in the general population. Although it is believed that neuromuscular training will specifically increase RFD and decrease injury, very few studies have investigated the relationship. The purpose of this study is to determine the effects of neuromuscular training on joint stability.

Methods

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Training Program for RFD

For a proper training program to be effective, considerations must be made for equipment used, exercises selected, order of these exercises, frequency of training, intensity of training, and volume of training. Optimal training conditions to increase RFD include the participant exerting (a) maximal force (b) throughout the entire range of motion of the exercise. Training with general strength training strategies presents challenges to the improvement of RFD Classic load-based exercises performed by athletes, such as the bench press and the squat, do not allow for maximal intensity to be performed throughout the entire range of motion because of the need to overcome the load to continue moving and the need to decelerate and the end of the range of motion. As a result, the development of RFD is compromised.

The current study was on the Ariel Computerized Exercise Machine (ACES). The ACES uses responsive kinetic technology, which is characterized by a resistive force that responds to the applied force. Using force transducers to measure applied forces, hydraulic resistance is controlled through a two-way feedback loop between the computer and the hydraulic system. Thus, responsive kinetic technology can control the speed at which a multi-joint movement is performed. In addition, the ACES uses a balanced lever arm with no external load.

As a result, responsive kinetic training allows for maximal effort throughout the entire range of motion with minimal eccentric loading (only body weight) and minimal muscle damage. Training with these conditions is ideal for RFD training, and allows for the design of specific exercises for specific functional movements that otherwise would not be possible. Because of these conditions, a greater increase in RFD is expected with responsive kinetic training.

Training sessions were twice per week for approximately thirty minutes. Exercises performed were squats, dead lifts, one-leg squats, and lateral squats. Participants performed three sets at 50% of their maximal velocity of movement. To measure maximum velocity, participants performed each exercise at speeds of 200 deg/s, which negated any hydraulic resistance and allowed the ACES to move as freely as possible. Individual sets lasted ten seconds in duration, during which as many reps as possible were completed.

To measure risk of injury and joint stability, the Reliability of the Landing Error Scoring (LESS-RT) was used [18]. The LESS-RT test asks each individual to jump off of a 30 cm box onto a target placed at the half of the individuals height. Participant were instructed to jump from the center of the box to the platform with two feet, minimizing jump height, and landing in the center of the platform. Then, they were instructed to jump vertically as high as possible and as quickly as possible. Participants were allowed a trial period to become familiar with procedures. Three trials were completed, and each trial was digitally recorded from both the sagittal and frontal views. After the completion of the jump tests, risk of injury was be determined based on ten aspects of the body's movements and landing sequences from the box to the platform. A scoring chart was used to score each of the ten aspects of movement, and the scores were summed. A lower score indicated a lower risk of injury.

Results

Using college-aged students, the effect of responsive kinetic training on the stability of the knee joint was evaluated using the LESS-RT. Average scores from three trials were recorded for pretest jumps (M =7.27, SD = 2.04) and post test jumps. (M = 5.37, SD =2.29). The pre and post statistics were compared using SPSS. Descriptive statistics (Table 1), and paired sample correlation (Table 2) are shown below. A paired sample t-test revealed significantly lower post test scores when compared to pre test scores (n=10, t=3.65, p=.005; Table 3). Results indicated a significant decrease in scores after kinetic training, suggesting joint stability increased.

Table 1. Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre	7.2680	10	2.03996	.64509
	Post	5.3660	10	2.28555	.72276

Table 2. Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre & Post	10	.715	.020

Table 3. Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre - Post	1.90200	1.64863	.52134	.72264	3.08136	3.648	9	.005

Discussion

The purpose of this study was to investigate the effects of responsive kinetic training on the stability of the knee join using the LESS-RT test before and after training. The results of this study described an increase in joint stabilization after a neuromuscular training program using responsive kinetic strategies. Increased joint stability was expected as a result of neuromuscular adaptations to training, indicating neural drive, increased neural transmission efficiency, fast twitch fiber selective recruitment, decreased muscle latency, and increased RFD. The result is an increase in RFD produced from the muscles surrounding the knee at the onset of contraction, increased joint stability, and a reduced risk of ACL injury.

Future Directions

Responsive kinetic training may also facilitate beneficial adaptations in the sensorimotor system that enhance dynamic restraint mechanisms and correct faulty jumping or cutting mechanics. The dynamic restraint system relies on feed-forward and feedback motor control to anticipate and react to joint movements or loads. [16] Feed-forward strategies employ muscle pre-activation to articular structures and are organized based on previous experience with sport-specific activities. [6,15,16] The feedback motor-control process involves a number of reflexive pathways that continuously modify muscle activity to accommodate unanticipated events. [15,16] For this reason, kinetic responsive training may enhance neuromuscular function and prevent knee injuries by increasing dynamic stability.

For example, the literature has shown that females involved in cutting and jumping are at greater risk for non-contact ACL injuries. Higher risk has been attributed to anatomical structure and hormonal levels. However, there have been no studies that have investigated RFD between males and females applied to joint stability. [5]

Similarly, in-season maintenance of athletes may be another area of targeted research. Because there is no eccentric load, responsive kinetic training would is likely be a highly effective in-season training program to maintain performance while decreasing risk of injury.

Conclusion

The purpose of the study was to determine the effect of neuromuscular training on the stability of the knee joint. It was hypothesized that neuromuscular training would increase RFD, and increase the stability of the knee. The results showed that neuromuscular training increased joint stability of the knee.

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