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Review Article

Plyometric Exercises

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ABSTRACT

Most sports involve fast movements for which forces must be generated quickly. In order to assist the athlete in training for power event the concept of plyometrics was introduced in Russia in 1969. Plyometrics is a traditional form of resistance training emphasizing the loading of muscles during an eccentric muscle action, which is quickly followed by a rebound concentric action. Plyometrics are also being used for lower and upper extremity rehabilitation. Many research studies have documented the effectiveness of plyometrics training on increasing power in the lower extremity. Very few research studies have documented the effectiveness of plyometric training on upper extremities. Although applicable to both upper and lower body, typically plyometrics exercises have involved jumping movements starting with a rapid lowering of body's centre of gravity (the eccentric muscle action component) from a standing position (termed a counter movement jump) or from an elevated surface (termed a drop jump) which is followed immediately by a jump in which the athlete tries to attain maximum height or distance (the concentric muscle action component). Plyometric training is most frequently completed using body weight rather than a mechanical load to provide the resistance, although weight can be attached to athlete to increase the resistance. Weighted implements, such as medicine balls, can also be used for training upper extremities.

Key words: Plyometrics, power, sports.

INTRODUCTION

Today's sports and recreation activities have become more and more competitive, with this increased competitive nature comes an increase in the desire to improve performance. Many techniques have been used over the years in an attempt to enhance performance and thus improve success. One of the most important aspects of performance enhancement, other than the skill is the ability to produce power. [1]

Success in many sports depends heavily upon the athlete's explosive leg power and muscular strength. [2] Three elements of muscle performance strength, power and endurance can be enhanced by some form of resistance exercise. [3]

Marked evidence indicates that regular participation in resistance training program can improve measures of strength and power in adults. Studies also suggest that changes in motor performance skills resulting from the performance of combined resistance training and plyometric training are greater than with either type of training alone, Thus both resistance training and plyometric training are typically recommended for adults when gain in motor performance are desired. [4-8]

It is logical that for athletes to seek to increase the rate of force development, because most sports involve fast movements for which forces must be generated quickly[4]. In order to assist the athlete in training for power event the concept of plyometrics was introduced in Russia in 1969. [9]

Plyometrics is a traditional form of resistance training emphasizing the loading of muscles during an eccentric muscle action, which is quickly followed by a rebound concentric action. [10,11] Presently, plyometrics are also being used for lower and upper extremity rehabilitation. [12] Numerous authors have documented lower quarter stretch shortening exercise drills and programs, but the literature is deficient in upper extremity stretch-shortening exercise programs. [13-17]

Definition

Plyometrics is a type of exercise training designed to produce fast, powerful movements, and improve the functions of the nervous system, generally for the purpose of improving performance in sports. Plyometric movements, in which a muscle is loaded and then contracted in rapid sequence, use the strength, elasticity and innervations of muscle and surrounding tissues to jump higher, run faster, throw farther, or hit harder, depending on the desired training goal. Plyometrics is used to increase the speed or force of muscular contractions, often with the goal of increasing the height of a jump. [18]

Plyometrics are exercises that enable a muscle to reach maximum strength in as short a time as possible. This speed and strength ability is known as power. [4]

Plyometric exercises are a quick, powerful movement using a pre-stretch or counter movement, which involves the stretch shortening cycle. The purpose of plyometric exercises is to increase the power of subsequent movements by using both the natural and elastic components of muscle, and tendon and the stretch reflex. [19]

Goal of plyometric exercises

Plyometric training is emphasized when the goal is to increase power. However, it is important to select plyometric drills that are movement specific; i.e. plyometric drills should be selected based on their similarity to movements that occur within the sport. [20, 21] Plyometrics consists of hopping, skipping, jumping and throwing activities designed to make the athlete faster. During the complex training method plyometrics must be done at maximum speeds; sub-maximal efforts will produce sub-maximal results. This is an application of the law of specificity. Going from slow muscles to fast muscles requires performing quick, “explosive” movements. These activities must allow for minimal contact with the ground (lower body) or the hand contact surface (upper body). Plyometrics are the best answer for these types of exercise needs. Lower body plyometric exercise emphasizes quick foot movements and the ability to get off the ground quickly. Upper body plyometric exercises emphasize using medicine balls to teach the muscle to respond more quickly to external forces. [22]

History

To simulate the explosive strength needed in athletics, Verkhoshanski advocated the "shock" method of training when he introduced the concept of plyometrics in Russia in 1969. [13]

The roots of plyometric training can be traced to Eastern Europe, where it was simply known as jump training or shock training. [14] "Plyo" originates from the Greek word, "plythein," which means to increase. "Plio" is the Greek word for "more," and "metric" literally means to measure. [23] The practical definition of plyometrics is a quick powerful movement involving a pre stretching of the muscle, thereby activating the stretch-shortening cycle. Therefore, one purpose of plyometric training is to increase the excitability of the neurological receptors for improved reactivity of the neuromuscular system. This type of sports performance training can be referred to as reactive neuromuscular training. [24] In effect, this type of approach is simply a muscle stretch-shortening exercise.

A literature review demonstrates that since 1969, many authors have used variances of Verkhoshanski's methodology in an attempt to establish the best stretch-shortening technique and training program. [25-30] Today, the chief proponents of the stretch- shortening approach are still found in the track and field society, since they continue to use Verkhoshanski's "reactive neuromuscular apparatus" for reproducing and enhancing the reactive properties of the lower extremity musculature. [30-32]

Theoretical Basis of Stretch-Shortening Exercise [33]

Stretch-shortening exercise uses the elastic and reactive properties of a muscle to generate maximal force production. In normal muscle function, the muscle is stretched before it contracts concentrically. This eccentric-concentric coupling, also referred to as the stretch-shortening cycle, employs the stimulation of the body's proprioceptors to facilitate an increase in muscle recruitment over a minimal amount of time. The proprioceptors of the body include the muscle spindle, the golgi tendon organ, and the joint capsule/ ligamentous receptors. Stimulation of these receptors can cause facilitation, inhibition, and modulation of both agonist and antagonist muscles. Both the muscle spindle and golgi tendon organ provide the proprioceptive basis for plyometric training.

The muscle spindle functions mainly as a stretch receptor. The muscle spindle components that are primarily sensitive to changes in velocity are the nuclear bag intrafusal muscle fibers, which are innervated by a Type l a phasic nerve fiber. The muscle spindle is provoked by a quick stretch, which reflexively produces a quick contraction of the agonistic and synergistic extrafusal muscle fibers. (Figure 1)

The firing of the Type l a phasic nerve fibers is influenced by the rate of stretch; the faster and greater the stimulus, the greater the effect of the associated extrafusal fibers. This cycle occurs in 3.5 msec and is mediated at the spinal cord level in the form of a monosynaptic reflex, such as the knee jerk. (Figure 2)

The golgi tendon unit, which is sensitive to tension, is located at the junction between the tendon and muscle both at the origin and insertion. The unit is arranged in series with the extrafusal muscle fibers and, therefore, becomes activated with stretch. Unlike the muscle spindle, the golgi tendon organ has an inhibitory effect on the muscle. Upon activation, impulses are sent to the spinal cord, causing an inhibition of the alpha motor neurons of the contracting muscle and its synergists and, thereby, limiting the force produced. It has been postulated that the golgi tendon organ is the protective mechanism against over contraction or stretch of the muscle. Because the golgi tendon organ uses at least one interneuron in its synaptic cycle, inhibition requires more time than Type l a monosynaptic interneuron excitation.

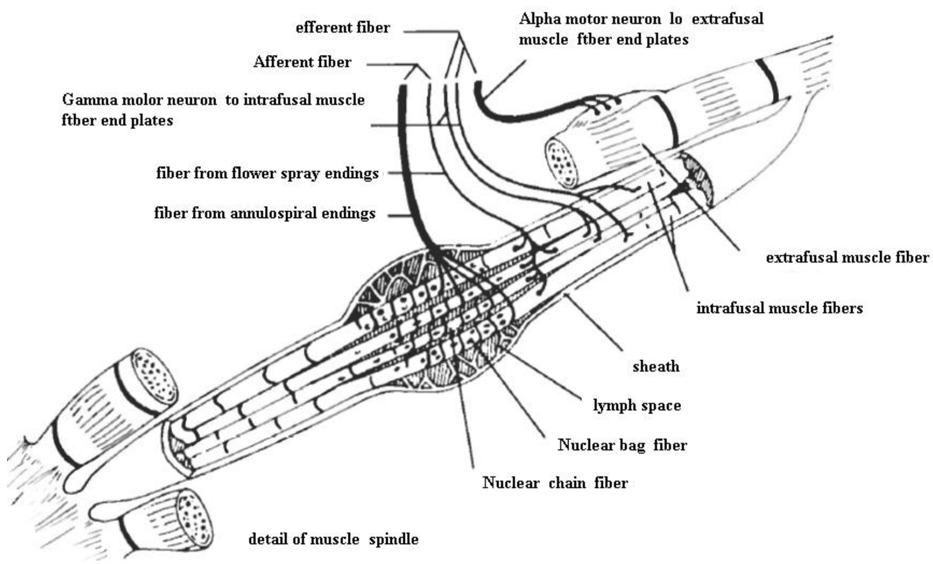

Figure: 1 Muscle spindle complex is a receptor consisting of intrafusal muscle fibers. Each spindle receives afferent innervation from group Ia (Aα) fibers and group II (Aα) fibers. The purpose of the muscle spindle is to provide information regarding muscular length to the central nervous system.

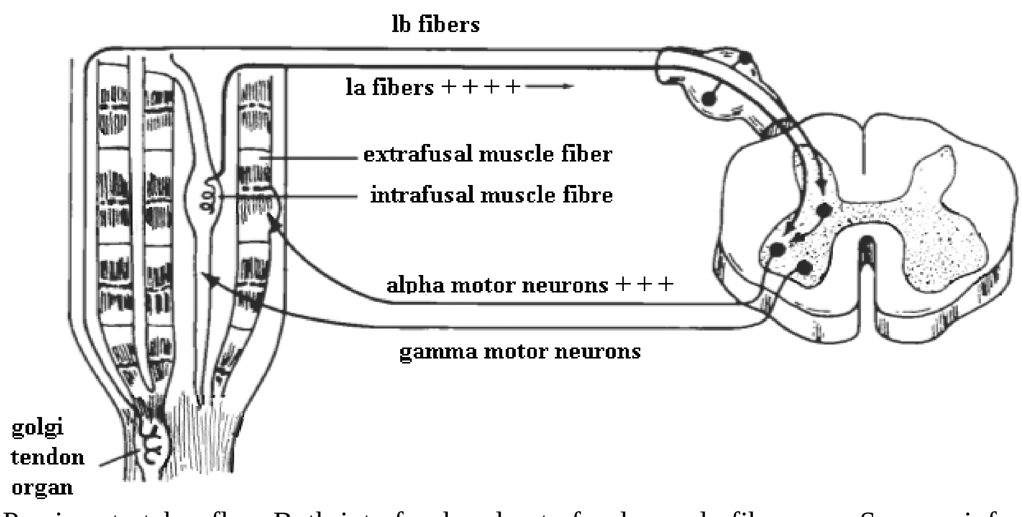

Figure: 2 Passive stretch reflex. Both intrafusal and extrafusal muscle fibers are. Sensory information is sent to the spinal cord via Ia fibers. The la fibers synapse on a motor nerve cell and excite it. As a result, motor impulses are sent back to the muscle via the alpha motor neurons, thereby causing muscle contraction.

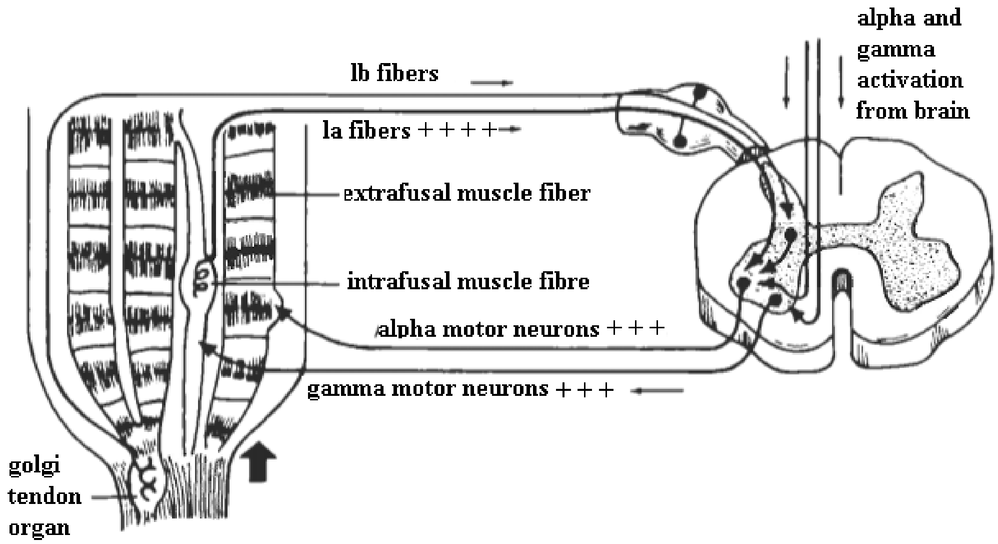

Figure: 3 Active eccentric-muscle contraction in which the muscle fibers lengthen. The muscle spindle and Golgi tendon organs oppose each other. The regulation of force is controlled by descending pathways from the brain.

During concentric muscle contraction, the muscle spindle output is reduced because the muscle fibers are either shortening or attempting to shorten. During eccentric contraction, the muscle stretch reflex generates more tension in the lengthening muscle (Figure 3).When the muscle tension increases to a high or potentially harmful level, the golgi tendon organ fires, thereby generating a neural pattern that reduces the excitation of the muscle. Consequently, the golgi tendon organ receptors may be a protective mechanism, but in correctly carried out plyometric exercise, their influences are overshadowed by the reflex arc pathway incorporated with excitation of Type l a nerve fibers.

In addition to the neurophysiological stimulus, the positive results of stretch-shortening exercise can also be attributed to the recoil action of elastic tissues. Several authors have reported that an eccentric contraction immediately preceding a concentric contraction will significantly increase the force generated concentrically as a result of the storage of elastic energy. The mechanism for this increased concentric force is the ability of the muscle to utilize the force produced by the elastic component. During the loading of the muscle, which occurs when stretching, the load is transferred to the elastic component and stored as elastic energy. The elastic elements can then deliver increased energy as it is recovered and used for the concentric contraction.

The muscle's ability to use the stored elastic energy is affected by time, magnitude of stretch, and velocity of stretch. Increased force generation during the concentric contraction is most effective when the preceding eccentric contraction is of short range and is performed quickly without delay.

The improved or increased muscle performance that occurs with the pre stretching of the muscle is the result of the combined effects of both the storage of elastic energy and the myotatic reflex activation of the muscle. The percentage of contribution from each component is not known at this time. In addition, the degree of enhanced muscular performance is dependent upon the time frame between the eccentric and concentric contractions.

Theoretically, stretch-shortening exercise assists in the improvement of physiologic muscle performance in several ways. While increasing the speed of the myotatic stretch-reflex response may increase performance, such information has not been documented in the literature. Research does support that the faster a muscle is loaded eccentrically, the greater the concentric force produced[35]. Eccentric loading places stress on the elastic components, thereby increasing the tension of the resultant rebound force.

A second possible mechanism for the increased force production involves the inhibitory effect of the golgi tendon organs on force production. Since the golgi tendon organ serves as a protective mechanism limiting the amount of force produced within a muscle, its stimulation threshold becomes the limiting factor. Desensitization of the golgi tendon organ may be possible, thereby raising the level of inhibition and, ultimately, allowing increased force production with greater loads applied to the musculoskeletal system.

The last mechanism by which plyometric training may increase muscular performance centers on neuromuscular coordination. The ultimate speed of movement may be limited by neuromuscular coordination. Explosive plyometric training may improve neural efficiency and increase neuromuscular performance. Utilizing the pre- stretch response may allow the individual to better coordinate the activities of the muscle groups. This enhanced neuromuscular coordination could lead to greater net force production, even in the absence of morphologic change within the muscles themselves, referred to as neural adaption. [14] In other words the neurological system may be enhanced to become more automatic.

Phases of Stretch Shortening Exercise

Three phases of the plyometric exercise have been described: the setting or eccentric phase, the amortization phase, and the concentric response phase. The eccentric or setting phase begins when the athlete mentally prepares for the activity and lasts until the stretch stimulus is initiated. Advantages of a correct setting stage include increasing the muscle spindle activity by pre- stretching the muscle prior to activation and mentally biasing the alpha motor neuron for optimal extrafusal muscle contraction. [34, 35] The duration of the setting phase is determined by the degree of impulse desired for facilitation of the contraction. With too much or prolonged loading, the elapsed time from eccentric to concentric contraction will prevent optimal exploitation of the stretch-shortening myotatic reflex. [13]

The second phase of the stretch-shortening response is the amortization phase. This phase is the amount of time between undergoing the yielding eccentric contraction and initiation of a concentric force. By definition, it is the electromechanical delay between the eccentric and concentric contractions during which the muscle must switch from overcoming work to imparting the necessary amount of acceleration in the required direction. [14]

Successful training using the stretch-shortening technique relies heavily on the rate of stretch rather than the length of the stretch. If the amortization phase is slow, elastic energy is wasted as heat, and the stretch reflex is not activated. The more quickly the individual is able to switch from yielding work to over- coming work, the more powerful the response.

The final period of the stretch-shortening exercise is the concentric response phase. During this phase, the athlete concentrates on the effect of the exercise and prepares for initiation of the second repetition. The response phase is the summation of the setting and amortization phases. This phase is often referred to as the resultant or payoff phase because of the enhanced concentric contraction. [14-16]

The implementation of the stretch-shortening program begins initially with the development of an adequate strength and physical condition base. The development of a greater strength base results in greater force generation as a result of both the increased cross-sectional area of the muscle and the resultant elastic component. In order to produce optimal strength gains, a structured plan must be instituted to prevent potential over-use injuries. [33]

Plyometric training programme [4]

Plyometric training program for pubescent athletes should begin as gross motor activities of low intensity. They should be introduced into warm ups and then added to sport specific skills. When designing the program an effective program accomplishes specific goals through manipulation of four variables: intensity, volume, frequency, and recovery.

Intensity is the effort involved in performing a given task, in plyometrics this means the type of exercise used, beginning with easy (skipping drills) and progressing to more difficult (alternate bounding).

Volume is the total work performed in a single workout session. This number will increase as the season progress. For lower body exercises a repetition is a ground contact.

Frequency is the number of repetitions performed as well as the number of times a session during a training cycle takes place. Typically 2-3 sessions of plyometrics can be completed in a week.

Recovery is a key variable in determining whether plyometrics will succeed in developing power or muscular endurance. For power training, longer recovery periods is needed (45 to 60 seconds).A work to rest ratio of 1:5 to 1:10 is required to assure proper execution and intensity of the exercise.

Safety precautions for Plyometric training [18]

1. Never begin a plyometric training program before a medical and orthopedic screening examination has been conducted.
2. Make sure that the participant has reaches a basic maturation level.
3. Develop adequate strength base
4. Always use good supportive shoes
5. Always use a good resilient surface
6. Always warm up and pre stretch
7. Always use a progressive overload(SAID principal)
8. Always use a proper organized progression
9. Make sure the participant can demonstrate proper landing before rebounding is taught
10. Always train with knowledgeable supervision
11. In addition to these general safety consideration, the instructor should look at several special considerations when developing the plyometric progression
    - The Participant's body structure
    - The Participant's body size
    - The Participant's injury history
    - The role of fatigue will play in the program

Contraindications to Plyometric Exercises [33]

1. Contraindications to performing plyometric upper extremity exercises include acute inflammation or pain,

immediate postoperative pathology, and gross shoulder or elbow instabilities.
2. The most significant contraindication to an intense stretch-shortening exercise program is non-involvement in a weight training program.
3. Intense stretch-shortening exercise programs are intended to be advanced strengthening programs for the competitive athlete to enhance athletic performance and are not recommended for the recreational athlete.
4. The clinician should be aware of the adverse reactions secondary to this form of exercise, such as post exercise soreness and delayed onset muscular soreness.
5. In addition, it should be noted that this form of exercise should not be performed for an extended period of time because of the large stresses that occur during exercise.
6. More appropriately, stretch-shortening exercise is used during the first and second preparation phases of training utilizing the concept of periodization.

Review of literature for plyometric exercise use

- Robert u. newton et al 1994 performed "Baseball throwing velocity :A comparison of medicine ball training and weight training" and found that A medicine ball training group showed no significant increase in throwing velocity but did show significant increase in strength.
- Heiderscheit et al. 1996 performed "The effects of isokinetic versus plyometric training on the shoulder internal rotators" and found that the plyometric group showed no significant change in any of the variables tested. The isokinetic group showed a significant increase in internal rotator power at 60°/sec eccentric, 120°/sec concentric and eccentric, and 240°/sec concentric and eccentric. The isokinetic group showed no significant change in any of the other variables tested.
- Chad Fortun, Thomas W. Kernozek et al 1998 performed "The effects of plyometric training on the shoulder internal rotators". They concluded that there were significant increases in passive ER, concentric isokinetic power at 180°/sec and 300°/sec, and softball throwing distance for the plyometric group. Plyometric training of the shoulder IRs improves isokinetic power, passive ROM, and functional performance as measured by a softball throw for distance.
- Daniel J. gehri et al 1998 performed "A comparison of plyometric training techniques for improving vertical jump ability and energy production". They concluded that depth jump training was superior to counter movement jump for improving vertical jumping ability and concentric contractile performance.
- Jeffery f. Vossen et al 2000 performed "Comparison of dynamic push-up training and plyometric push-up training on upper-body power and strength" and they concluded that The PPU group experienced significantly greater improvements than the DPU group on the medicine ball put t here was no significant difference between groups for the chest press, although the PPU group experienced greater increases.

- Kathleen A. Swanik et al. 2002 performed “The effects of shoulder plyometric training on proprioception and selected muscle performance characteristics” and they found that plyometric activities facilitate neural adaptations that enhance proprioception, kinesthetic and muscle performance characteristics.
- Goran Markovi et al 2005 performed “Effects of sprint and plyometric Training on morphological characteristics in physically active men”. They concluded that the short-term explosive-type training programmes in which muscles operate in the fast stretch-shortening cycle conditions (i.e., sprinting, jumping) have a limited potential to induce morphological changes in physically active men.
- Rahman Rahimi et al 2005 performed “The effects of plyometric, weight and plyometric-weight training on anaerobic power and muscular strength”. The results showed that all the training treatments elicited significant improvement in all of the tested variables. However, the combination training group showed signs of improvement in the vertical jump performance, the 50 yard dash, and leg strength that was significantly greater than the improvement in the other 2 training groups (plyometric training and weight training). This study provides support for the use of a combination of traditional weight training and plyometric drills and leg strength.
- Michael G. Miller et al 2006 performed ‘The effect of 6 week plyometric training on agility” and their study concluded that plyometric training can be an effective training technique to improve athlete’s agility.
- Rahman Rahimi et al 2006 performed, “Evaluation of plyometrics, weight training and their combination on angular velocity” and the results showed that all the training treatments elicited significant improvement in angular velocity. However, the combination training group showed signs of improvement in the angular velocity that was significantly greater than the improvement of the other two training groups (plyometric training and weight training). It was concluded that a combination of traditional weight training and plyometric drills "complex training" enhance angular velocity production in cycling. Therefore, complex training may help improve performance in sprint cycling that requires angular velocity, angular acceleration and power.
- Andrew B.carter et al 2007 performed “Effect of high volume upper extremity plyometric training on throwing velocity and functional strength ratios of the shoulder rotators in collegiate baseball players and they concluded that ballistic six training protocol can be beneficial supplement to a baseball athlete’s off season conditioning by improving functional performance and strengthening the rotator cuff musculature.
- Avery D. Faigenbaum et al 2007 performed “Effects of a short-term plyometric and resistance training program on fitness performance in boys age 12 to 15 years”.

Participants were randomly assigned to either a resistance training group (RT, n = 14) or a combined resistance training and plyometric training group (PRT, n = 13).. At baseline and after training all participants were tested on the vertical jump, long jump, medicine ball toss, 9.1 m sprint, pro agility shuttle run and flexibility. The PRT group made significantly greater improvements than RT in long jump (10.8 cm vs. 2.2 cm), medicine ball toss (39.1 cm vs. 17.7 cm) and pro agility shuttle run time (-0.23 sec vs. -0.02 sec) following training. These findings suggest that the addition of plyometric training to a resistance training program may be more beneficial than resistance training and static stretching for enhancing selected measures of upper and lower body power in boys.

- Vladan Milić1 et al 2008 performed "the effect of plyometric training on the explosive strength of leg muscles of volleyball players on single foot and two-foot takeoff jumps". In this study the sample of measuring instruments consisted of eight tests of explosive leg strength: the two-foot takeoff block jump, the right foot takeoff block jump, the left foot takeoff block jump, the two-foot takeoff spike jump, the right foot takeoff spike jump, the left foot takeoff spike jump, the standing depth jump and the standing triple jump. They concluded that there was a statistically significant difference in explosive strength in favour of the plyometric training group. They determined an increase in explosive strength for the two-foot and single foot takeoff jumps.
- Thomas, Kevin et al 2009 preformed "the effect of two plyometric training techniques on muscular power and agility in youth soccer players ." and found that Post training, both groups experienced improvements in vertical jump height ($p < 0.05$) and agility time ($p < 0.05$) and no change in sprint performance ($p > 0.05$). There were no differences between the treatment groups ($p > 0.05$). This study has concluded that both Depth jump and Counter movement jump plyometrics are worthwhile training activities for improving power and agility in youth soccer players.
- Chetna Chaudhary, Birendra Jhajharia 2010 performed **"**Effects of plyometric exercises on selected motor abilities of university level female basketball players". They have concluded that the plyometric training is an effective means for improving the following variables: agility, flexibility vertical jump and movement speed. On the other hand, plyometric training is not an effective means for improving the variable, that is, speed of movement (20-m dash). There was no significant improvement in case of control group.

SUMMARY

Evidence showed that Plyometric exercises have been used successfully by many athletes as a method of training to enhance power. In order to realise the potential benefits of plyometric training the stretch-shortening cycle must be invoked. This requires careful attention to the technique used during the drill or exercise. The rate of stretch rather than the magnitude of stretch is of primary importance in plyometric training. In addition, the coupling time or ground contact time must be as short as possible. The challenge to you as coach or athlete is to select or create an exercise that is specific to the event and involves the correct muscular action. As long as you remember specificity and to ensure there is a pre-stretch first then the only limit is your imagination. Plyometric exercise and weight training can be combined in complex training sessions to develop explosive power.

REFERENCES

1. Wilk K.E., Arrigo. Current concepts in the Rehabilitation of the athletic shoulders. J. orthop Sports Phys. 1993; 18 (4): 365-378.
2. Rahman Rahini, Naser Behpur. The effects of plyometric, weight and plyometric weight tranning on an anaerobic power and muscular strength. J. phy edu and sports. 2005; 3(1): 81 -91.
3. Carolyn Kisner, Lynn allen. Therapeutic Exercises. JAYPEE: 5th edition.
4. Chu, D A.1998.Jumping in to Plyometrics. Human Kinetics, Champaign, IL: 2nd edition
5. Adams K., O'Shea J.P., O'Shea, K.L. and Climstein. The effect of six weeks of squat, plyometric and squat-plyometric training on power production. J. Strength and Conditioning Research. 1992; 6: 36-41.
6. Fleck S.J. and Kraemer W.J.Designing resistance training programs. Human Kinetics, Champaign, 2004;IL: 3rd edition.
7. Fatouros I.G., Jamurtas, A.Z., Leontsini D., Kyriakos T., Aggelousis N., Kostopoulos N. et al.Evaluation of plyometric exercise training, weight training, and their combination on vertical jump performance and leg strength. J. Strength and Conditioning Research. 2000; 14: 470-476.
8. Polhemus, R., Burkhart, E., Osina, M. and Patterson, M. The effects of plyometric training with ankle and vest weights on conventional weight training programs form men and women. J Strength and Conditioning Research 1981;2:13-15,
9. Verkhoshanski Y. Perspectives in the improvement of speed-strength preparation of jumpers. Phys Educ Sports. 1969; 4: 28-29,
10. Duda, M. Plyometrics: A legitimate form of power training. Phys. Sports med. 1988;16: 213–218,
11. Steben, R.B., A.H. Steben. The validity of the stretch shortening cycle in selected jumping events. J. Sports Med. 1981; 28–37,
12. Chad Fortun, Thomas W. Kernozek. The Effects of Plyometric Training on the Shoulder Internal Rotators. Ph. D thesis.
13. Verkhoshanski Y. Depth jumping in the training of jumpers. Track Technique 1983;51:1618-1619,
14. Voight M, Draovitch P. Eccentric Muscle Training in Sports and Orthopaedics. New York: Churchill Living stone, 1991; 45-73.
15. Chu D. Plyometric exercise. Nat Strength Condition Assoc.1984;6(1):56-62,.
16. Chu D. The language of plyometrics. Nat Strength Condition Assoc 1984.6(4): 30-31.
17. Costello F. Bounding to the Top. Los Altos: Taf new Press, 1984.
18. http://en.wikipedia.org/wiki/Plyometrics
19. Baechle, R. & Earle, W.Essentials of strength training and conditioning. National strength and conditioning

association. USA: Human Kinetics 2000; 2nd edition,
20. Hedrick, A. Manipulating Strength & Conditioning Programs to Improve Athleticism. J Strength and Conditioning Research. 2002; 24(4): 71–74.
21. Holcomb W. R., Kleiner D. M. & Chu D. A .Plyometrics Considerations for safe and effective training. J Strength and Conditioning Research1998; 36 – 39,
22. Chu, D. Explosive power and strength: complex training for maximum results. 1996; USA: Human Kinetics,.
23. Wilt F. Plyometrics, what it is and how it works. Athl 1975; 55(5):76-90.
24. Wilk K. E., Voight M. L. Plyometrics for the overhead athlete. The Athletic Shoulder, 1993;New York: Churchill Livingstone,
25. Assmussen E, Bonde-Peterson F. Storage of elastic energy in skeletal muscle in man. Acta Physiol Scand1974; 91: 385- 392.
26. Bosco C, Komi P. Potentiation of the mechanical behavior of the human skeletal muscle through prestretching. Acta Physiol Scand 1979; 106: 467-472.
27. Bosco C, Komi PV. Muscle elasticity in athletes. In: Komi PV, Exercise and Sports Biology, Champaign, 1982; IL: Human Kinetics.
28. Bosco C, Tarkka I, Komi W. Effects of elastic energy and myoelectric signals during stretch- shortening cycle exercise. Int I Sports Med.1982; 2:137.
29. Cavagna C. Elastic bounce of the body. I Appl Physio197 ;129(3): 29-82.
30. McCarlane B.Special strength: Horizontal and vertical. Track Field Q Rev1983; 83(4):51-53.
31. Adams T. An investigation of selected plyometric training exercises on muscular leg strength and power. Track Field Q Rev1984; 84(1): 36-40.
32. Blattner S, Noble L. Relative effects of isokinetic and plyometric training on vertical jumping performance. Res Q, 1979; 50(4): 583-588.
33. Kevin E. Wilk, Michael Voight, Michael A. Keirns. Stretch Shortening Drills for the Upper Extremities: Theory and Clinical Application.J Sport. Phy Ther. 1993; 17: 225-239.
34. Allman FL: Sports Medicine, 1974; New York: Academic Press.
35. Lundin PE. “A review of plyometric training”. Nat Strength Condition Association 1985; 7(3):65-70.

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