The Use of Plyometrics in Martial Arts Training

Introduction

Proficiency in any martial art requires a significant amount of training in all aspects of physical fitness: flexibility, speed, endurance, strength, agility, power, coordination, balance, timing, and precision, just to name a few. Whereas some of these abilities are innate, many of them can be improved with directed training. Further, many (if not most) of these components are inter-related, and can be trained simultaneously. For example, by definition, power is a combination of strength and speed. Thus, training either strength or speed (or both) should help improve power. Similarly, by training and controlling speed, one can positively affect both timing and agility. One efficient and effective training method that helps to improve many of these components simultaneously is "plyometrics."

Plyometrics, also known as "stretch-shortening training," consists of exercises or drills in which muscles are stretched, and then contracted in such a way that the muscles' natural rebounding effect is used to create an explosive reaction. Studies have shown that training in such a way can have a positive effect on strength, speed, power, and agility [2,3,4,5,6,7,8,9].

This paper will attempt to provide a short introduction to Muscle Physiology including the contraction mechanism and elastic properties, provide a scientific explanation of the basic principles of plyometric training, list the contraindications to such training, discuss the benefits as they pertain to martial arts, give examples of specific exercises, and discuss plyometrics as a component of a complete martial arts training program.

Muscle Contraction and Related Mechanics

Before we can discuss the principles of plyometric training, we must first understand the physiology and mechanics of muscles. Let us first examine the physiological mechanism of muscle contraction, as all human movement is controlled by such contractions.

A "muscle group" consists of a set of muscles that contract in conjunction to cause a specific movement. Within these muscle groups, are individual muscles which themselves are comprised of muscle fibers. Strands of proteins called myofibrils run the length of each of these muscle fibers, and contain actin and myosin. When a nervous impulse is received from the central nervous system, assuming there is sufficient fuel near the proteins, the myosin is drawn toward the middle of the muscle fiber, pulling actin with it. In affect, this causes the muscle fibers to shorten. This shortening of muscle fibers causes the muscle group to shorten, producing a muscle contraction.

Muscle contractions can be classified into three different categories: (1) Concentric contraction, (2) Eccentric contraction, or (3) Isometric contraction.

Concentric contraction occurs when the muscles shorten during movement. An example of a concentric contraction is the curling of a dumbbell. When flexing

the arm (reducing the angle at the elbow joint), the bicep muscles shorten, producing enough force to draw the dumbbell upwards. Generally, this type of contraction causes a reduction in joint angle.

Eccentric contraction occurs when the resistance is greater than the force generated by the muscle contraction. In this case, individual muscle fibers contract, but the length of the muscle as a whole increases throughout the movement. An example of this is the extension or straightening of the elbow joint to lower a dumbbell from the flexed position. In this case, the weight of the dumbbell is greater than the amount of force generated by the biceps, and so the biceps lengthens as the weight is being lowered. Generally, this type of contraction causes an increase in joint angle.

Isometric contraction occurs when the individual muscle fibers contract, but the length of the muscle group does not change. More specifically, isometric contraction occurs when the muscles contract, but no body movement takes place. If you were, for example, to press the palms together in front of the body, you would produce an isometric contraction. In general, these types of contractions cause no change in joint angles.

Muscle Elasticity & the Stretch Reflex

Another attribute that allows the human body to move efficiently is the elasticity of muscle tissue. During concentric and eccentric contractions, a muscle lengthens and shortens, not unlike a rubber band or a spring that has been stretched and released.

Continuing with the former analogy, the rubber band possesses what could be considered potential elastic energy when stretched. Further, if stretched sufficiently, and not held in the stretched position for an extended period of time, it will have a tendency to return to its original length with force when released, possibly contracting temporarily to a shorter length then before it had been stretched at all. This tendency to shorten again is known as the "stretch" or "myotatic" reflex.

This myotatic reflex is partially based on the speed at which the muscle is stretched. Thus, the faster a muscle is stretched, the greater the concentric contraction in response [1].

Principles of Plyometrics

Plyometric training is designed to take advantage of concentric and eccentric contraction in combination with muscle elasticity and the stretch reflex. More specifically, it is the eccentric contraction that stretches the muscles, causing the myotatic reflex. This reflex causes the muscles to begin to shorten so that if a concentric contraction immediately follows, it can use the release of potential elastic energy to help the muscle contract. The length of time between the eccentric and concentric muscle contractions determines the amount of energy that is transferred to the subsequent contraction, and is known as the amortization phase. The shorter this phase, the more energy transferred. Due

to this additional energy, a concentric contraction tends to be stronger and more explosive when preceded by the myotatic reflex.

In general, then, plyometric training consists of exercises that cause an eccentric contraction, and is then immediately followed by a concentric contraction, ideally with the shortest possible amortization phase to transfer potential energy.

Research has shown that the amortization phase is a neuromuscular action that can be improved with practice [6]. Thus, one component of plyometric training is to concentrate on shortening the length of time between each concentric and eccentric contraction.

Contraindications for Plyometric Training

Because the goal of plyometric training is to elicit maximal concentric contraction to produce an explosive, powerful action, such training is not recommended for everyone. The drills that are used for such a program are generally considered advanced techniques, and not recommended for beginning athletes for a variety of reasons.

In particular, it is recommended that athletes first develop a foundation of strength before attempting plyometrics. Some researchers have gone so far as to recommend that an athlete be able to squat 1.5 to 2.0 times their own body weight before starting a plyometric training regimen [1,10,11,13]. More current research suggests that such a rigid limitation may not be necessary, but does suggest a conservative, cautious approach before beginning such a program [12].

Others have suggested that athletes weighing over 220 pounds should use caution in performing certain plyometric drills that involve jumping, as the amount of force generated on landing has the potential to lead to knee or other lower leg injury. The National Strength and Conditioning Association recommends that these athletes not perform certain jumps from higher than 18" platforms [10]. Further research is necessary to corroborate these findings, but in the interest of safety, this should be a consideration.

Additionally, research has found that plyometric training is most efficient when combined with strength training programs, so it is generally recommended that athletes continue strength training beyond building the required foundation of strength and may, in fact, see the fastest results when performing such training after a strength session [14,15].

Also, many beginning athletes need to build up their kinesthetic sense (also known as proprioception), or their awareness of how their body moves and where it lies in space when performing complex techniques. This plays a significant role in balance. If, after the eccentric contraction of a plyometric drill, the athlete does not have control of his/her balance, safety may be compromised. One study has suggested that athletes be able to stand on one leg in a half-squat position for thirty seconds before considering plyometric training, particularly depth jumps (as described below) [10].

Additionally, it should be noted that plyometric training is contraindicated for children who have not yet reached puberty. In addition to the fact that young athletes frequently have not developed a foundation of strength or proprioception, exercise physiologists have determined that such training may also cause damage to the growth (epithyseal) plates that have not yet closed. [16]

Benefit to Martial Arts

The science of plyometrics gained prominence in the early 70s as Eastern European athletes dramatically increased the level of success in a multitude of sports that required speed, power, and explosiveness. In particular, athletes from these countries excelled in track & field, gymnastics, and power lifting. Their success lead to some in-depth scientific analysis of European training methods, of which a primary component was plyometrics [1].

Since that time, numerous peer-reviewed, scientific studies have found that plyometric training provides numerous benefits to the competitive athlete. Salonikidis K, Zafeiridis A. (2008) found that plyometric drills improved reaction time, lateral and linear speed, power and strength for novice tennis players [3]. Marques MC, Tillaar R, Vescovi JD, González-Badillo JJ.(2008) found that a 10-week plyometric program combined with strength training increased strength by as much as 15%, and power output by as much as 12% in female volleyball players[4]. de Villarreal ES, González-Badillo JJ, Izquierdo M.(2008) found that plyometric training improved sprint times, vertical jump height, and jump contact times (reduced time to land jump, and initiate another jump, which could be classified as agility) in athletes [6]. Chappell JD, Limpisvasti O. (2008) also found that such training increased vertical leap as well as the ability to hop from a single leg. Additionally, they found that the neuromuscular adaptations of such training decreased the likelihood of knee injuries to athletes [7]. Mangine GT, Ratamess NA, (2008) found that plyometric training could improved maximal strength and lower body power in athletes [8]. And Perez-Gomez J, Olmedillas H (2008) found that plyometric training improved kicking performance for football players [5].

Thus, it is obvious that plyometric training has great potential benefit to the martial artists. All the benefits in these studies can be applied to martial arts:

- reaction time

- linear speed

- lateral speed

- vertical leap

- strength

- power

- reduced jump contact times/agility

- ability to hop from a single leg

- neuromuscular adaptations that may reduce knee injury

- kicking performance

Reaction time, linear speed, lateral speed, agility, and kicking performance are all attributes that play a role in the success in martial arts sparring competition, such as Taekwondo Kyorugi or Karate point-sparring. Improved reaction time, linear speed, lateral speed, strength, and power are all benefits to athletes in the grappling arts, such as Judo, Jujitsu, and Yong Mu Do. Linear speed, lateral speed, vertical leap, power, agility, ability to hop from a single leg, and kicking performance are all important characters for performing martial arts demonstration techniques, such as Wushu forms competition and Taekwondo Demonstration in the Hanmadang competition or Creative Poomse competition. And any martial art that performs board-breaking would benefit from its athletes improving speed, strength, and power.

Equipment & Practice Environment

Plyometric training involves explosive movements, and many including jumps. Therefore, such training should be performed on a soft surface to prevent injury. A grass field or a floor lined with cushioning mats provides a safe cushion from impact.

Wooden boxes or other platforms that allow some give when landed on are necessary for many plyometric drills. Because of the variation in both the height of athletes and the intensity of different exercises, a variety of these devices of different heights (or height-adjustable devices) are recommended.

Hurdles or plastic cones can also be useful for such training. This equipment is useful for drills in which an athlete must jump over or around something. In many instances, a length of string can substitute for this equipment.

Medicine balls, especially balls that bounce, are invaluable tools for development of strength and power for the upper body. Handles or some other type of grip can be useful, but aren't necessary for most of these activities.

Other weights, such as Russian kettle bells (round weights encased in a soft vinyl casing with handles attached) can also be useful for plyometric training.

Exercises

The training principle of specificity states that "any training program should reflect the desired adaptation. The closer the training routine is to the requirements of the competition, the better the outcome will be" [17]. In other words, a training program is most effect when the exercises and drills partaken most resemble the actions of competition. Thus, if the goal is to improve power when kicking, then the training exercises most effective to elicit this effect should mimic powerful kicks.

Thus, the plyometric exercises described below bear at least some similarity to motions performed when participating in martial arts, and are only a small

sample of possible plyometric exercises:

Upper Body Exercises:

(1) Plyometric pushups

a. Lay prone (face down) on the floor

b. Position the palms flat on the floor about shoulder-width apart, next to the chest but below the

shoulders

c. Press up into a push-up position, keeping the body straight

d. Lower the body to the floor while maintaining the straight position (This is the eccentric phase)

e. As soon as the chest gets within 5 inches or so of the floor, press up forcefully enough that the

hands come off the floor and the body is propelled upward; there should be no pause at the

bottom of the movement as this is the amortization phase, and the press up is the concentric

phase.

f. Once the hands have landed back on the ground and the body has stabilized, then a short pause

of 1-5 seconds is allowed.

Applicability to martial arts: The pressing motion can help improve the speed and power of hand strikes, such as punches. The pressing motion is also useful for creating space from within a clench while sparring, or grappling.

(2) Supine ball tosses

a. Lay face up (supine) on the floor with a partner standing above you near your head

b. Extend the arms upwards with the palms face-up, read to catch a medicine ball

c. Your partner will hold a medicine ball above your chest, and drop it into your hands

d. As the ball is dropped, catch it and bend your elbows, lowering the ball to your chest (This is

the eccentric phase)

e. As soon as the medicine ball is close to your chest, do not pause (as this is the amortization

phase), and push pass the ball straight up for your partner to catch (This is the concentric phase)

Applicability to martial arts: Same as for the plyometric push-ups, plus catching the medicine ball helps with the muscular adaptation of receiving and absorbing an external force, such as when an opponent launches a close-range attack during sparring

(3) Ball Toss for Height

a. Stand straight, with legs slightly wider than hip-width apart

b. Grip a medicine ball with both hands at waist level

c. Bend the knees into a quarter- to half-squat, while lowering the medicine ball between the legs

(eccentric phase)

d. Without pausing (reducing the amortization phase), forcefully straighten the legs while

simultaneously swinging the arms up over your head, and throw the medicine ball straight up

and slightly behind you. If done forcefully, the body will leave the ground, essentially jumping

(concentric phase)

e. Make sure the medicine ball does not land on you or anyone else

Applicability to martial arts: The lowering of the body with the lower legs, and the subsequent arm swing can help with coordination and timing. Thus, this drill can help with jump kicks and jumping in general. Further, the arm motion working against resistance can help develop the motion necessary to throw an opponent when grappling.

(4) Twisting Ball Passes to a Partner

a. Stand with the feet slight about shoulder width apart, back-to-back to a partner who is about 2-3

feet away from you

b. Hold a medicine ball with both hands in front of you at about waist height or chest height

c. Turn the torso to the left moving the ball to the left as well (eccentric motion)

At the same time, your partner will turn his right. Thus, at the peak of each of your turns, you

will be facing each other

d. As soon as you are within reach, hand the ball to your partner and, without pausing (to minimize

the amortization phase), turn back the opposite direction (the concentric motion), ready to

receive the ball from your partner

e. As soon your partner receives the ball, he/she will rotate the opposite direction, and prepare to

pass the ball back to you

f. These motions are to be repeated in a continuous motion for the prescribed number of repetions

Applicability to martial arts: The turning motion builds the core strength of the abdominal muscles and lower back muscles for rotational strength and power. Since both strikes and blocks are more powerful when the core strength is used to supplement leg or arm strength, building such core strength is invaluable to the martial arts. This drill is also useful for improving twisting jumps such as the 540 and butterfly twist in Wushu. Additionally, rotational strength and power in the core can help with throws and sweeps in grappling.

(5) Sideways Slams

a. Face away from wall about 3 feet away, with the feet about shoulder width apart, holding a medicine ball with both hands. (For this drill, it's best to use a medicine ball that does not bounce, if available)

b. Rotate the body to your left, keeping the ball in front of your torso (eccentric motion); you can

think of this as the "wind-up" for a throw.

c. Without pausing (minimizing the amortization phase), twist the torso rapidly in the opposite

direction and release the ball into the wall (concentric motion)

d. Retrieve the ball, and repeat going the opposite direction.

Applicability to the martial arts: This drill has the same benefits at the Twisting Ball Pass to a Partner

(6) Downward Slam/Bounces

a. Stand with the feet slightly wider than should with apart, holding a medicine ball with both

hands at waist height, and bend your legs into a squat (this is the starting position)

b. Straighten the legs into a standing position while simultaneously lifting the ball overhead with

both hands (eccentric phase)

c. Then, without pausing (to minimize the amortization phase), return to the squat position while

simultaneously bring the hands down, and release the ball, slamming it into the ground, or

bouncing it slightly in front of you if you have a bouncing medicine ball (concentric phase)

Applicability to martial arts: The upward and downward motions of the arms helps building explosiveness in the arms, shoulders and back, and are similar to the motions used for many throws in grappling. Additionally, the coordination of the upper and lower body to achieve the greatest amount of force can help with the wind-up phase of most jumps, so this is useful for jump kicks in many martial arts or jumps in Wushu.

(7) Pull-Over Pass

a. Lay face-up (supine) on your back, bend the knees, and position the feet flat on the floor

b. Position a partner facing you, a short distance away from your feet

c. Hold a medicine ball in both hands, bring the ball past your head until your arms are almost

parallel to the ground

> d. Then, as you sit up, swing your arms forward and toss the medicine ball to your partner, as if throwing a soccer ball back into play

e. Remain sitting up until your partner tosses the ball back to you. Then catch the ball, and return

back to the original position (eccentric motion)

f. As soon as your arms have straightened again and your back is on the floor, immediately (to

minimize the amortization phase) sit up and pass the ball back to your partner again

Applicability to martial arts: This drill provides added resistance over regular sit-ups, building strength in the core abdominal muscles. This should lead to improved power for many martial arts techniques, since power frequently comes from the core. The catching/passing motions should help improve strength and power in the shoulders and back, and mimics a motion common to throws in the grappling arts.

(8) Backward Throw

a. Stand with the feet slightly wider than should width apart, holding a medicine ball at waist level

in both hands

b. Squat down, bending the knees and lean slightly forward at the hips, lowering the ball between the feet (eccentric motion)

c. As soon as the ball reaches its lowest point, immediately explode upwards, extending the legs,

and toss the ball upwards and behind you

Applicability to martial arts: The throwing motion builds strength and power performing an action that closely resembles a Judo throw.

Lower Body Exercises:

(1) Standing Vertical Jump

a. Stand sideways, next to a wall with the feet should width apart, and then raise both arms

overhead (If the athlete would like to measure vertical leap, first stand directly next to the wall,

and place a piece of tape on the wall at the highest point the fingers can reach when the arm is

raised overhead)

b. Bend the knees into a squatting position, while simultaneously swinging the arms down and

behind the body (eccentric phase)

c. As soon as the body reaches the lowest point that is comfortable for the athlete, immediately

(minimizing the amortization phase) swing the arms up while simultaneously springing up from

the legs and jumping as high as possible (concentric phase). (The difference between the height

reached and the measurement taken in step (a) is the athlete's vertical leap).

Applicability to martial arts: This drill emphasizes explosive extension of the hips, knees and ankles. Thus, in addition to the obvious potential to increase vertical leap, this exercise should also develop explosive action of the entire leg when kicking. The improved vertical leap, of course, would prove advantageous for jumping kicks in karate, Taekwondo, Wushu, or any other martial art that uses jumping kicks.

(2) Bounding

a. Begin with feet about should width apart, one foot farther in front than the other

b. Bring the rear leg forward while simultaneously pushing off from the ankle with both feet

c. As soon as the foot that was in the rear lands forward (eccentric phase), immediately repeat step

(b), but with the opposite side

d. Repeat for 6 to 10 foot ground contacts

This drill is a bit difficult to describe, but should look be composed of a series of one leg hops

that, when done consecutively in a quick manner, looks a bit like running.

Applicability to martial arts: This drill emphasizes explosive extension of the ankle and knee, so it should help develop general foot speed, which is useful for most martial arts. The improved speed with ankle flexion should also help improve kicks.

(3) Zigzag Bounding

a. Zigzag bounding is almost identical to regular Bounding, except that each foot strike is done

forward and laterally, so that the complete motion causes the body to move in a slalom or zigzag

motion.

b. Repeat for 6 to 10 foot ground contacts

Applicability to martial arts: This drill provides the same benefits as regular bounding, with the addition of developing agility, since the athlete practices changing directly quickly. Footwork agility is very important in most types of martial arts sparring.

(4) Bounds into a Sprint

a. The first part of this drill is identical to regular Bounding. However, after the first 3 or 4 foot

contact, break into a sprint for 5 to 10 meters

Applicability to martial arts: In addition to the same benefits as regular bounding, this drill mimics the motion the "wind-up" motion of a running jump kick, which is normally comprised of a few strides followed by an explosive movement. The sprint at the end would, of course, also aid in the development of general speed.

(5) Lateral Barrier Jumps

a. Stand sideways next to short barrier (ideally, a soft box, short rod balanced on two plastic cones,

or other object that will not cause the athlete to trip if the object is not cleared when jumping

over it)

b. Jump with both feet laterally, clearing the box

c. Land with both feet (eccentric phase)

d. Then, without pausing (minimizing the amortization phase), jump back to the starting position

(concentric phase)

Applicability to martial arts: This drill will help improve vertical leap, as well as agility. Thus, this exercise can help improve jump kicks, and will improve the speed in which an athlete can change direction during sparring activities.

(6) Lateral High Jumps

a. Stand sideways next to a wooden box on your right

b. Place your right foot on top of the box

c. Drive upward using the right leg, bringing the body upwards and over the box

d. Land with right leg on the floor, and the left on top of the box (eccentric phase)

e. Then, immediately repeat the same motion with the left leg propelling the body upwards and

over the box, landing into the same position as in step (b)

f. This completes one repetition. Repeat for the recommended number of reps.

Applicability to martial arts: Builds quadriceps strength, necessary for deep stances in many martial arts, including Taekwondo and Wushu. The action of switching feet should also help improve general coordination, footwork, and agility.

(7) Single leg hops

a. Stand with feet about shoulder width apart

b. Lift one leg

c. Hop forwards as far as possible on the other foot

d. Land, doing a single leg half-squat (eccentric motion)

e. Immediately hop again, hopping continuously

Applicability to martial arts: Develops explosive forward motion, useful for initiating attacks in sparring, or improving the speed for footwork. Additionally, because this drill is performed on one leg, balance can also be improved, as well as the initiation of kicks.

(8) Star jumps

a. Squat down, as low as is comfortable

b. Extend the legs as quickly as possible straight up, propelling the body upwards into a jump

c. As the body is propelled upwards, extend all 4 limbs such that they are fully extended at the

peak of the jump

d. As the body descends, flex the limbs back into position so that you can land back into the

original squat position (this landing motion is the eccentric phase)

e. As soon as you land back into the original position, immediately explode into another jump

(minimizing the amortization phase)

f. Repeat the squat- jump-squat motion continuously for the prescribed number of repetitions

Applicability to martial arts: Improves vertical leap, which is useful for jumping kicks. Also, the explosive extension of the limbs can help improve speed for kicks and punches.

(9) Spinning Jumps

a. From a standing position, raise one arm into the air

b. Lower the body into a half-squat, and then explode upwards into a jump

c. At the same time, rotate the body 360 degrees

d. Land back into the half-squat position (eccentric phase)

e. Immediately (minimizing the amortization phase) initiate another jump, this time spinning in the

opposite direction for 360 degrees (concentric motion)

(10) Split jumps

a. Begin in a standing position with the feet slightly wider than should width apart

b. Squat down as far as is comfortable

c. As soon as you reach the lowest position of your squat, immediately jump up into as wide of

side split as possible

d. Then land back into the squat stance as in step (b) (eccentric motion)

e. And immediately (minimizing the amortization time) launch into another split jump (concentric

motion)

Applicability to martial arts: The explosiveness should improve power in hip and knee flexion, critical attributes of powerful kicks. The split jump should help with dynamic flexibility, also an important component of most martial arts.

(11) Alternating Scissor leg jumps

a. Begin with the legs approximately shoulder width apart, but one foot forward from the body,

and the other rearwards of the body

b. Squat down into a half squat

c. Explode upwards propelling the body upwards

d. As the body travels upwards, switch the position of the feet so that when you land, the foot that

started forward of the body is now behind, and vice-versa for the other foot

e. When you land, you should naturally return to the half squat position as in step (b) (eccentric

motion)

f. As soon as you land, immediately (to minimize the amortization phase) launch into another

jump, and switch feet position again

Applicability to martial arts: The scissoring motion of the legs mimics the motion of many jump kicks, thus, this drill should improve those techniques. The scissor motion can also help improve dynamic flexibility and footwork for sparring.

(13) Depth jumps from a Box

a. Stand on a wooden box or other device, 6-18 inches off the ground

b. Step off the box, and bring your feet together so that they land simultaneously

c. Absorb the landing by moving into a half- to full-squat position (eccentric motion)

d. As soon as your body reaches its lowest point in the squat, immediately (to minimize the

amortization phase), extend the legs while swinging the arms upwards, propelling yourself into

a jump (concentric motion)

Applicability to martial arts: Depth jumps improve vertical leap, provides the opportunity for neuromuscular adaptation to absorbing shock through the legs, and improves agility. Thus, this drill is useful for improving jump kicks, as well as quick changes of direction.

Plyometrics as a Component of a Training Program

Plyometric training can prove extremely efficient at improving strength, speed, power and agility. However, it is also considered a very intense activity. Thus, the volume of such drills should not be so large that it interferes with regular training, or (in the worst case) lead to injury.

Further, as previously mentioned, these exercises are most efficient when the athlete is also doing strength training on a regular basis [14,15].

In general, plyometrics should be done 2-3 times per week at the most. During the off-season when athletes aren't competing, such sessions can be very efficient in improving speed, strength, power and agility. During competition season, however, it's generally recommended that these sessions to reduced to once or twice a week, and scheduled such that the athlete has at least 48 hours rest before performing another intense workout. Thus, if the athlete has an intense sparring workout one day, a plyometric training session should not occur the next day.

Since these types of exercises do require explosive movement in combination with significant coordination of movement, they should be done after a thorough warm-up. They should slo not be performed when the athlete is fatigued, as technique would likely be compromised.

Because many of these drills involve jumping, which can force the body to absorb as much as 3 times the athlete's body weight when landing, coaches usually limit the amount of "foot contacts" an athlete can have per session. There are many variables in determining a specific number, including the athlete's strength, weight, and experience doing these types of drills; however, some studies have suggested that the average athlete perform no more than 120 ground contacts per session [10].

In general, a plyometrics session should be comprised of 5-10 different exercises. Each drill should be repeated 5-10 times (repetitions), which completes a set. Each set should be repeated once or twice more for a total of 2-3 sets. Because these drills do attempt to elicit maximum speed and power from the muscles, complete recovery should be allowed between sets, usually 3-5 minutes [10].

Conclusion

The martial arts require that its practitioners possess a multitude of physical

attributes, including strength, speed, power, and agility. Modern scientific research in the field of exercise physiology has found that plyometric drills, which take advantage of the elasticity of muscle and its stretch reflex, help improve all of these physical abilities. Thus, it would be to the martial artists' advantage to include plyometric training as part of a safe, efficient training regimen.

Endnotes

1. Chu, Donald, Jumping Into Plyometrics, 2nd Ed. (Champaign, IL: Human Kinetics, 1998):5.

2. Iide K, et al, "Physiological responses of simulated karate sparring matches in young men and boys," Journal of Strength and Conditioning Research (May 2008):839-44.

3. Salonikidis K and Zafeiridis A., "The effects of plyometric, tennis-drills, and combined training on reaction, lateral and linear speed, power, and strength in novice tennis players," Journal of Strength and Conditioning Research (Jan 2008): 182-191.

4. Marques MC, et al, "Changes in strength and power performance in elite senior female professional volleyball players during the in-season: a case study," Journal of Strength and Conditioning Research (Jan 2008).

5. Perez-Gomez J, et al, "Effects of weight lifting training combined with plyometric exercises on physical fitness, body composition, and knee extension velocity during kicking in football," Applied Physiology, Nutrition and Metabolism (June 2008):501-510.

6. de Villarreal ES, et al, "Low and moderate plyometric training frequency produces greater jumping and sprinting gains compared with high frequency," Journal of Strength and Conditioning Research (May 2008):715-725.

7. Chappell JD and Limpisvasti O., "Effect of a neuromuscular training program on the kinetics and kinematics of jumping tasks," American Journal of Sports Medicine (June 2008):1081-1086.

8. Mangine GT, et al, "The effects of combined ballistic and heavy resistance training on maximal lower- and upper-body strength in recreationally trained men," Journal of Strength and Conditioning Research (Jan 2008):132-139.

9. Mihalik JP, et al, "Comparing short-term complex and compound training programs on vertical jump height and power output," Journal of Strength and Conditioning Research (Jan 2008):47-53.

10. National Strength and Conditioning Association. Position statement: Explosive/plyometric exercise. National Strength and Conditioning Association Journal (1993):16.

11. Chambers C, et al, "Time course of recovery of vertical jump height and heart rate versus running speed after a 90-km foot race," Journal of Sports Science (1998):645-651.

12. Holcomb WR, et al, "Plyometrics: Considerations for safe and effective training," Strength Conditioning (1998):36-39.

13. Wathen D., "Literature review: Plyometric exercise," National Strength and Conditioning Association Journal, (1993):17-199.

14. Bompa TO. Periodization Training for Sports. (Champaign,IL: Human Kinetics, 1999).

15. Baechle TR and Earle RW. Essentials of Strength Training and Conditioning: 2nd Edition. (Champaign, IL: Human Kinetics, 2000).

16. Lipp EJ. "Athletic Physeal Injury in Children and Adolescents," Orthopedic Nursing (1998):17-22.

17. Brooks, G and Fahey, T, Fundamentals of Human Performance (New York, NY: Macmillan Publishing Company, 1987):13.