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Weightlifting Exercises Enhance Athletic Performance That Requires High-Load Speed Strength

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summary

Weightlifting exercises can be effective for enhancing athletic performance. This article provides a biomechanical and physiological discussion as to why weightlifting exercises are useful to improve athletic performance and how they may be integrated into a training program.

Weightlifting is a sport in which athletes compete for the total weight of 2 lifts: the snatch and the clean and jerk. The training methods used in this sport are also used as a method of strength training for a wide range of other sports. Weightlifting exercises can be effective for enhancing athletic performance that requires high-load speed strength such as football, basketball, volleyball, and track and field events because of their biomechanical characteristics of high force and power output (11, 21). Weightlifting exercises include the snatch, clean and jerk, and variations of these such as the hang snatch, hang clean, snatch pull, and clean pull. The purpose of this article is to provide a biomechanical and physiological discussion as to why weightlifting exercises are useful to improve athletic performance and how they should be performed in a training program.

Why Are Weightlifting Exercises Recommended?

Expression and Development of Power

Power is the ability of the neuromuscular system to perform work over a given time period or, alternatively, the product of force that can be exerted at a given velocity of movement. For the majority of sports performances, power output is the critical mechanical quantity required rather than force production, that is, strength (17). As proposed by Newton and Dugan (16), 7 independent qualities contribute to an athlete's power capacity: maximum strength, high-load speed strength, low-load speed strength, rate of force development, reactive strength, skill performance, and power endurance. Each sport requires various combinations of these strength qualities, and this characterizes how power is best developed to match these demands. Therefore, all the strength qualities should be taken into account when evaluating the power profile of athletes, and the focus of training should be set from the point of not only specificity of a sport but also the individual athlete's capacity in each of these qualities (16, 17). Newton and Kraemer (17) have proposed that greatest training efficiency for power development will occur when the athlete's least developed power qualities are identified and then specifically targeted for training emphasis in the program design.

In the process of diagnosing each athlete's power qualities and planning the training program, speed strength is classified into 2 qualities based on the load: high-load and low-load speed strength (16). High-load speed strength is evaluated by power output with a relatively heavy load (i.e., >30% of max), and low-load speed strength is referred to as power output without external load or with a light external load (i.e., <30% of max). To assess speed strength of the lower extremities, jump squat is often used. Jump squat without load represents low-load speed strength, and jump squat with a load of 55% of 1 repetition maximum (1RM), for example, indicates high-load speed strength. Power output in jump squat with several different loads (i.e., 30, 55, and 80% of 1RM) gives us a profile of speed strength (16). However, relatively expensive equipment (e.g., position transducer or force plate) is needed to measure power output in jump squat, and most athletes and coaches do not have access to such equipment. When the equipment is not available, the combination of the following measures may be useful to diagnose power capacity for the lower extremities: 1RM squat for maximum strength, 1RM power clean for high-load speed strength, and vertical jump for low-load speed strength. If an athlete's vertical jump height is good but 1RM power clean is low, the athlete needs to improve high-load speed strength. If this is the case, training for high-load speed strength such as using weightlifting exercises should be considered.

Weightlifting Exercises Improve High-Load Speed Strength

To enhance maximal power, athletes need to perform training movements that involve rapid acceleration against resistance, and this acceleration should extend throughout the movement with no intention to decelerate at the end (19). Almost all rapid movements in sports exhibit such an acceleration profile; therefore, the training method that mimics this profile would likely induce desirable sport-specific adaptation. During the pull phase of the clean and snatch and the drive phase of the jerk, athletes extend their hips, knees, and ankle joints to push against the ground as hard and as rapidly as possible at a given weight, producing just such an acceleration profile for the barbell and body. The kinematics and kinetics are remarkably similar to jumping (2, 8). Importantly, there is no need to control the upward movement of the weight to actively decelerate the barbell, for this is achieved by the influence of gravity. In fact, athletes never decelerate the upward movement in weightlifting exercises until extension is complete. Thus, weightlifting exercises from a biomechanical evaluation are an excellent method to train high-load speed strength.

In contrast, other types of strength-training exercises intrinsically contain deceleration movements. Even if athletes try to keep accelerating their movements, they are required to decelerate the weight at the end of range of motion. Otherwise, the weight is released from their hands or injury may occur to their musculoskeletal structures because of the kinetic energy they must absorb (5, 19). In this manner, speed strength cannot be improved efficiently.

Plyometric exercises such as jumping, hopping, and bounding use the stretch shortening cycle and enhance athletes' power output in the concentric phase (1, 5). These types of exercises have the same characteristic as weightlifting exercises in that they do not require decelerating movements. Plyometric exercises can be used to improve low-load speed strength but not high-load speed strength. Because these exercises are performed with only the athletes' own body weight, or a relatively small weight such as a medicine ball, the load is not high enough to improve high-load speed strength.

When an athlete performs a jump exercise with high load, such as jump squats (countermovement vertical jump with barbell or dumbbells), the result is a very specific and effective exercise for developing high-load speed strength (25). However, this exercise may cause injuries to the lower leg, knee, back, and neck because of the high impact at landing (13). To overcome this problem, several different electronic and mechanical systems have been developed. Studies have reported that such systems enhance high-load speed strength effectively while reducing the risk of injury (12, 13, 18). For example, Newton et al. (18) used a Smith machine equipped with an electromagnetic braking system, which removed 75% of the barbell weight during the eccentric phase of jump squats. They reported significant improvement in vertical jump performance and the high-intensity power training to be well tolerated. However, limited numbers of athletes have access to such systems at this time because the systems are not in widespread practical use.

Evidence to Support That Weightlifting Exercises Improve Athletic Performance

Several studies have investigated the relationship between weightlifting exercises and jump performance (2, 3, 8, 11, 21). Canavan et al. (2) compared the movements of the hang power snatch from above the knee to those of noncountermovement (concentric only) vertical jump using collegiate athletes who were familiar with these exercises. The authors reported similarities in maximal power, time to maximal power, relative power, maximal force, and time to maximal force between the hang power snatch and the vertical jump movements. Garhammer and Gregor (8) showed that ground reaction force in the snatch was similar to that of countermovement vertical jump. The biomechanical similarities between the snatch and the vertical jump help explain the findings from Stone et al. (21) and Carlock et al. (3). Stone et al. (21) reported that the weightlifting exercises improved vertical jump height and 1RM of snatch and clean significantly. Carlock et al. (3) also showed a strong correlation between weightlifting performance and jump performance in weightlifters. Although these studies are not definitive, they suggest that weightlifting exercises are effective for improving jump performance. However, further research involving long-term training interventions is required.

In our laboratory, one subject performed the hang power clean and coun-

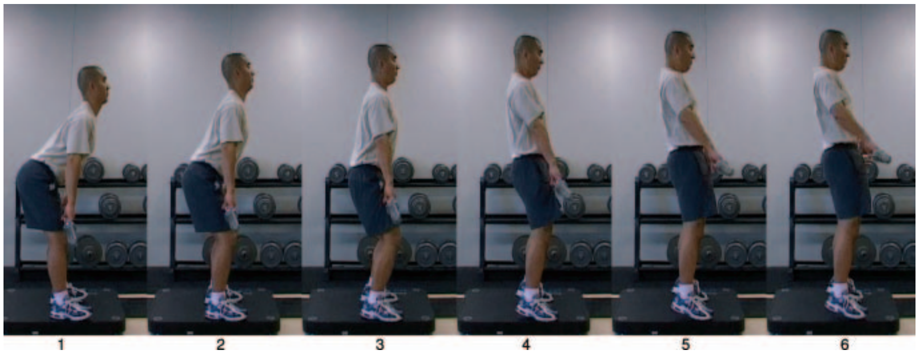

Figure 1. Hang power clean (transition phase: 1–3; second pull phase: 4–6).

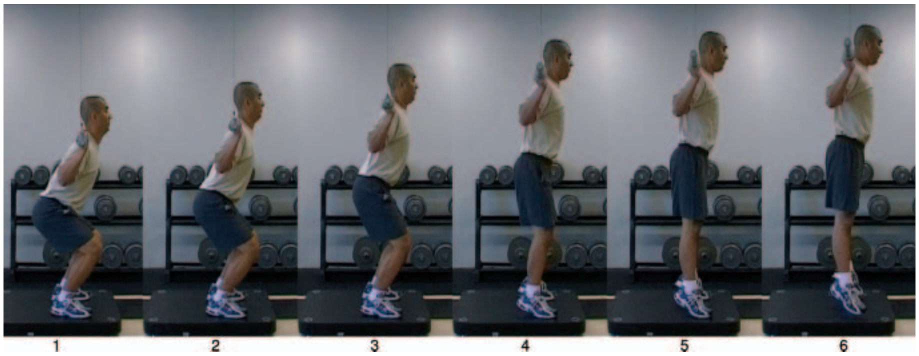

Figure 2. Squat jump (ascending phase).

termovement squat jump on a force plate. The kinematic similarities in hip and knee extension can be observed during the hang power clean (transition and second pull phase) and squat jump (ascending phase) from Figures 1 and 2. In addition, upon examination of the vertical ground reaction force, marked similarities were in both the magnitude and the shape of the force time curve (Figure 3).

Few studies have addressed the effects of weightlifting exercises on sprinting, stopping, changing direction, and throwing. Stone et al. (23) reported a strong correlation between isometric clean pull and throwing performance (shot put and weight throw). But, in general, few studies have investigated effects of weightlifting training in comparison with other types of resistance training on athletic performance. Hoffman et al. (11) compared weightlifting and powerlifting in 20 college football players. One group participated in a program consisting mainly of weightlifting exercises, and the other group participated in a program consisting predominantly of powerlifting exercises (squat, bench press, and deadlift). The authors found that the weightlifting group improved jump performance significantly more than the powerlifting group. However, no significant difference was found between groups for improvement of sprint and agility performance. This may be because all subjects participated in sprint form drills, agility drills, and conditioning sessions in addition to weightlifting or powerlifting exercises during the last 5 weeks of their training periods.

As a research priority, biomechanical and physiological studies are required to investigate the training effects of weightlifting exercises on athletic performance other than jumping to address this gap in scientific knowledge.

How Weightlifting Exercises Are Introduced into a Training Program

Equipment

As long as athletes perform with good technique and use proper equipment, weightlifting exercises are as safe as or safer than other sports and activities (22). The correct equipment, which includes bumper plates and platforms, is desired in order to safely introduce weightlifting training. This equipment allows athletes to drop barbells after they receive the weight or whenever necessary. In addition, barbells themselves should have certain levels of quality because the shafts need to rotate smoothly during the receiving phase of the clean and snatch. Otherwise, athletes may injure their wrists, elbows, or shoulder when they receive the barbell. With a set of barbells, plates, and platforms, athletes can perform a variety of different exercises and train almost all muscle groups. Although a set of weightlifting equipment can cost more than $1,000, purchasing weightlifting equipment is much less expensive than purchasing several single-movement machines, which is a further advantage of this training method. Also, as can be seen in numerous examples around the world, weightlifting training can be performed by large numbers of athletes simultaneously.

Techniques

Teaching proper exercise technique is one of the most important tasks of strength coaches. It is readily apparent that beginners have difficulty learning the techniques of the clean and snatch from floor. Because the second pull phase exhibits higher force and power output than the first pull (6, 7), it may be better for strength coaches to introduce the clean and snatch from the hang position (or from boxes) so that the technique is simplified and lifters still take advantage of the second pull phase. Newton (15) recommended that athletes should learn the receiving position first and then learn the second pull. Hedrick (10) has proposed 12 steps for teaching the clean: education, modelling, foot position, hand position, grip, start position, jump shrug, low pull, high pull, clean, adjusting foot position, and squat clean. This teaching method can be also applied for teaching the snatch. By following the 12 steps, athletes will learn the second pull phase of the snatch and clean more easily.

To learn techniques of weightlifting exercises, athletes should always use the weights that they can lift safely. At the beginning of training, athletes may prefer to use a wooden pole or polyvinyl chloride pipe and then a bar without weights. Eventually, athletes should add 10 to 20 lb to each set depending on their skill progression. If the strength coach notices that an athlete does not perform correct technique at any stage, he or she should have the athlete use lighter weight until proper technique is achieved.

Strength coaches must monitor the exercise techniques of their athletes during the training. Schilling et al. (20) have stated that if athletes perform the clean and snatch with proper technique, their feet should not be displaced forward but rather slightly backward. Chiu and Schilling (4) have also described that the feet remain in the same vertical plane in which they started the movement. Therefore, strength coaches need to observe athletes' feet displacement during weightlifting exercises and give feedback immediately after every repetition (rep).

Designing a Program

There are 5 variables to design a weight training workout: exercises, loads, reps, sets, and rest periods. Strength coaches should consider these variables carefully to meet the purpose of training. If the purpose of training is to improve high-load speed strength, weightlifting exercises are an excellent selection.

To train high-load speed strength by using weightlifting exercises, athletes need to use the weight that maximizes mechanical power output. Power is a product of force and velocity, and there is an inverse relationship between the two (1, 5, 17). Therefore, when athletes use heavy weights, force output is high but velocity will be low, and vice versa. Haff et al. (9) reported that the clean pull at 80% of 1RM power clean produced higher power output than that of 90% and 100%. Moore et al. (14) showed that the hang power clean at 70% or lighter loads produced lower power output than that of 75% or higher loads. These results may suggest that loading 75 to 80% of the athletes' 1RM maximizes power output during weightlifting exercises. However, if athletes' skill levels are inadequate, they should focus on learning proper technique by using the weight that they can lift safely. Further research is required about the effects of training experience on the optimal load for power output in each of the lifts.

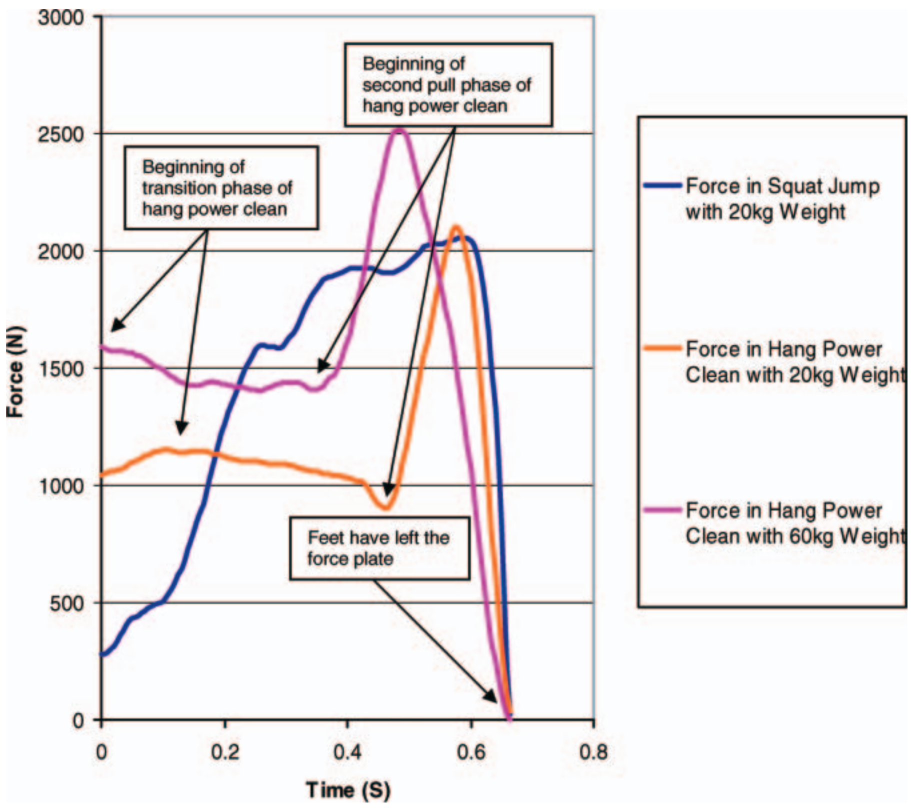

Figure 3. Force characteristics in second pull phase of the hang power clean and ascending phase of squat jump.

Theoretically, rep and load have an inverse relationship. If an athlete needs to use a heavy weight, he or she cannot perform many reps. If an athlete needs to perform many reps, the load must be relatively low. If an athlete needs to improve high-load speed strength, he or she should perform all reps with high power output. If an athlete's power output becomes significantly low (≤90% of initial value) during the set because of fatigue, either the reps are too many or the loads are too heavy. Typically, when competitive weightlifters or strength and power athletes perform weightlifting exercises (snatch and clean), their number of reps per set is 5 or fewer (1).

Athletes are generally recommended to perform 3 to 5 or 6 sets for each exercise (1, 5). Strength coaches should consider the influence of fatigue if the aim of training is high-load speed strength. If athletes' power outputs are significantly impaired at the fifth or sixth set because of fatigue, it would not be effective to improve their high-load speed strength. At present, no study has monitored the influence of fatigue on performance of weightlifting exercises during consecutive sets. However, Wendell et al. (24) monitored the change of performance (mean velocity) of weighted jump squat training through 10 sets of 5 reps at 70% load of their 1RM squat and found that the performance was significantly impaired by the sixth set. If the key point is to improve high-load speed strength, athletes should perform every rep and set at as high of a power output as possible. Therefore, athletes are suggested to take 2-, 3-, or even 5-minute rests between sets to maximize power output (1).

However, if the main focus of training is power output under a fatigued condition (e.g., to improve blocking performance in football after several consecutive drives), the rest period between sets is shortened. In this condition, it may be necessary to reduce the load regarding the fatigue level to minimize decreases in power output. It is also important for strength coaches to consider the selection of exercise such that exercises with relatively less difficulty (e.g., clean pull from mid thigh) and not exercises that require high skill (e.g., snatch from floor) are preferable.

Conclusion

In this article we have presented a biomechanical rationale as to why weightlifting exercises are effective for improving athletic performance that requires high-load speed strength. When strength coaches include weightlifting exercises in training programs, it may be better for them to introduce variations such as the hang clean first so that they can simplify their teaching process and that athletes can still take advantage of high velocity and high power output. If athletes have adequate levels of exercise technique, it is suggested that they use 75 to 80% of 1RM load, with 5 or fewer reps per set to improve high-load speed strength.

However, it is also evident that more research is necessary to investigate the efficacy of weightlifting exercises in comparison with other types of resistance training. More training studies are necessary to investigate the effect of weightlifting exercise on athletic performance. ♦

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