POWER DEVELOPMENT:

The periodised strength training plan proposed by Bompa (11) commences with anatomical adaptation, is followed by maximum strength and progresses to the power conversion phase which is in turn followed by a maintenance period and concludes with a regeneration phase. The aim of this power phase is to convert the gains made in the maximum strength phase into a sport-specific combination of strength- either power or muscular endurance. It is during this period when the gains of the previous phases should be converted into specific movement speeds and patterns of the particular sporting performance. For the purpose of this article, discussion will be limited to the power aspect. Explosive movements are required in many sports and are typically performed at high speeds against resistance. In these sports, the explosiveness may be more important that maximum force production (maximum strength). The optimal training resistance method for developing fast force production is widely debated by researchers. In light of this controversy, a review on the subject is appropriate.

NEURAL FACTORS THAT INFLUENCE THE FORCE AND RATE OF FORCE PRODUCTION

Young (50) and Schmidtbleicher (39) reveal that these are intra-muscular coordination and intermuscular coordination.

1) Intra-muscular coordination: this is dependent on the extent of motor unit activation within a muscle and is determined by:

a) Recruitment: the number of active motor units

b) Firing rate of motor units

c) Synchronised motor unit firing

d) Stretch reflex input

2) Inter-muscular coordination- the coordination between muscles and muscle groups (skill) and influenced by:

a) Activation of synergists

b) Co-contraction of antagonists

Since the development of inter-muscular coordination is basically skill training, it can only be maximised by using loads that resemble the skill in terms of both movement speed and pattern so that technique is not altered drastically. A general exercise for the leg muscles (squat) using a heavy load is relatively more effective for development of intra-muscular coordination than inter-muscular coordination, whereas the using light loads e.g. weighted vest should be more effective for developing inter-muscular coordination (51).

FORCE -VELOCITY RELATIONSHIP

Explosive resistance training increases the slope of the early portion of the force time curve (maximum rate of force development). Although heavy resistance training increases maximum strength, the highest point of the force time curve, this type of training does not improve power significantly. This is because the movement time during explosive activities is typically less than 300ms and most of the force increases cannot be realised over such a short time. Maximal power is produced at intermediate velocities of movement, that is, at approximately 30% of maximum shortening velocity (36,38).

HEAVY V's LIGHT LOADS

Research has found cases for using both methods for developing power. However, the argument that is usually put forward is that heavy resistance strength training with high loads and slow contraction velocities leads to improvements primarily in maximum strength and is demonstrated by specific shifts in the high force portions of the force-time curve. However, power training that utilizes high contraction velocities and low loads produces changes in the early parts of the force-time curve which is vital for sports involving short contraction times.

HEAVY LOADS

The rationale behind heavy loads for increasing power is anecdotal in nature.Olympic style lifts have been proposed for developing explosive power (24,25). This has been due to the fact that weightlifters usually exhibit exceptional power during vertical jump and sprinting. As a result, this style of training has been promoted to increase explosive power. During weightlifting, power output is extremely high and speed of movement is fast. Further, such lifts have an explosive, accelerative velocity profile, making them much more specific than traditional resistance training exercises to explosive power performance in other sport activities.

Buehrle & Schmidtbleicher (14) studied the influence of maximal strength training on movement speed. They revealed that the three groups (maximal group, power group and isokinetic group) all showed significant improvement in strength and speed, with the maximal group in particular raising the ability to apply available maximal strength as quickly as possible (correlation between maximum strength and movement speed was raised from r= -.40 to r= -.88). Further studies (16,31,32,41,42,43,46) have also shown improvements in explosive strength values and performance as a result of maximum strength training.

LIGHT LOADS

Gambetta (23) reveals that during the majority of resistance training programs, most of the time and effort is spent on the upper left (high force, slow velocity area) of the force velocity curve. However, most athletic performances occur on the lower right of the curve (low force, high velocity) where powerful movement is the priority. He suggests that training should be based upon increasing optimum rather than maximum strength as optimum strength training increases performance whilst maximum strength increases force.

Studies on isokinetic testing and training methods have found that strength increases are specific to the velocity at which one trains (2,18,19,26,27,28,29,35).This suggest that resistance training should be performed at a high speed if explosive power is to be developed.

Wilson et al (47) compared the effects of 10 weeks of training on vertical jump performance using traditional back squats, explosive jump squats (30% of 1RM) or plyometrics in the form of depth jumps. All training groups produced increases in vertical jump performance, but the explosive power group had significantly greater increases (18%) than the other 2 groups (heavy resistance training 5%; drop jump training 10%). Further, the heavy resistance training group and the plyometric group showed no significant decrease in 30m sprint time (0.01secs) whilst the explosive power group decreased sprint time significantly (0.05secs). Further research by Berger (6) also had similar results. The group which used an explosive jump squat (50-60% of 10RM) improved significantly when compared to the group which trained with 10RM, static training or vertical jumping. This suggests the use of light loads to improve power.

Further research by Pedemonte (37) provides information on explosive training based on the results of a study conducted by Soviet researchers. Subjects used loads 30,40,50,60,70% of 1RM during a hang snatch. Athletes performed continuous repetitions until speed decreased. With a load of 30% of 1RM, the athletes where able to maintain speed for 21 seconds, at 40% speed lasted for 12 seconds whilst at 50% speed lasted for 6 seconds. Based on this information he suggests loads of 30-40% of 1RM when seeking to develop high speed strength.

A further argument against the use of heavy loads to develop power has been proposed by Elliott et al (22) who revealed that when lifting a 1RM weight, the bar is decelerating for as much as 24% of the concentric movement. The deceleration phase increases to 52% when performing the lift with a lighter resistance, eg. 81% of 1RM. Plyometric training and weighted jump squats avoid this problem by allowing the athlete to explode all the way through the movement.

Light loads are based on the notion that they allow the generation of maximum mechanical output. A case against this is that mechanical power output may not be essential for successful performance in many sports. For instance in long, triple and high jump events, take-off ability is essential and is strongly influenced by reactive strength and explosive strength (44). Therefore, speed/strength methods targeted at these qualities (plyometrics) are more specific than targeting the development of maximum mechanical power.

COMBINING LIGHT AND HEAVY LOADS

Harris et al (30) compared the effects of three weight training programs on measures of athletic performance: maximum strength, power, speed and agility. Group 1 performed loads at 30% of maximum isometric strength, group 2 performed loads at 80-85% 1RM, group 3 alternated between a heavy day (80-85% 1RM) and light day (55-60% 1RM). Group 1 improved significantly ($p<0.05$) in 1/4 squat, mid-thigh pull, vertical jump (VJ), Margaria-Kalaman (MK) power test, and standing long jump (SLJ). Group 2 improved significantly in squat, 1/4 squat, mid-thigh pull and MK. Group 3 improved significantly in squat, 1/4 squat, mid-thigh pull, vertical jump (VJ), Margaria-Kalaman (MK) power test, standing long jump (SLJ), 10yd shuttle and vertical jump power index. The study revealed that combining heavy and light weights produced the best results.

INTENDED SPEED OF MOVEMENT

Behm & Sale (5) compared the training response of ballistic unilateral ankle dorsiflexions against resistance that either rendered the resultant contractions isometric (one limb) or allowed a relatively high velocity movement (other limb). Training produced the same high velocity specific response in both limbs. The results suggest that it is the intention of moving a load quickly which elicits the high velocity training response. This argument is often put forward by supporters of the use of heavy loads to develop power.

COMBINING WEIGHT TRAINING AND PLYOMETRICS

There have been numerous studies which suggest that by combining weights and plyometrics you will increase power more than weights or plyometrics alone (3,7,17,21,34,40). Adams et al (1) compared the effectiveness of three different training programs- squat, plyometrics and squat and plyometrics in increasing hip and thigh power production as measured by the vertical jump. All three groups showed a significant increasing hip and thigh power. The combined squat and plyometric group showed a statistically greater improvement ($p<0.0001$) than squat or plyometrics alone.

PLYOMETRICS, POWER AND SPEED

Plyometrics aim to bridge the gap between strength and speed. Plyometric exercises accentuate the eccentric phase of muscle contraction thus increasing the relationship between maximum strength and power. By achieving this, explosive movements and quicker reactions are developed. During plyometric activities the stretch-shortening cycle (SSC) is activated. By using plyometrics to develop the SSC, athletes are better able to accelerate their bodies or sports implements and generate greater force at high velocities, therefore improving performance (10,15,45). Numerous studies have established the effectiveness of plyometric drills in improving power (1,4,8,9,10,12,13,17) and speed (10,15,20,33,45,48,49).

CONCLUSION

The research suggests that there are strong arguments for the use of heavy or light loads, combining heavy and light loads, the intention of quick movement on heavy loads, combining weights and plyometrics and the use of plyometrics alone in order to develop power. For these methods to be effective there needs to be transfer into specific movement speeds and patterns of the particular sporting performance. Research suggests that by combining weights and plyometrics and by combining plyometrics and speed, power is increased compared to each exercise performed alone. Therefore, it would be logical to assume that by combining maximum weights, plyometrics and speed training in the one session, power would be increased even further. Anecdotal evidence suggests that this is the optimal method for maximum power conversion.Therefore extensive research into this area is recommended.

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