# Resistance Training - Part 2: Considerations in Maximizing Sport Performance

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## Introduction

Basic exercises are exactly that - basic. In general, they are very straightforward and there is little need to substitute other movements in their place or supplement them with different types of assistance exercises intended to target the muscles differently. This is not a concrete rule, however, and some prudent alternatives are offered below. Long-term variety is often best achieved by adjusting the workload for a limited number of movements rather than attempting to include every possible exercise. Commonly used exercises include squats, pulling movements and presses.

Considering the concept of "basic exercise", strength training exercises can be classified into three categories:

1. Primary or "structural" ...multi-joint, weight bearing (e.g., weightlifting movements, squat, deadlift).
2. Secondary or "supplemental" ...multi-joint, non-weight bearing (e.g., upper-body pressing or pulling exercises).
3. Tertiary or "isolation" ...single-joint, non-weight bearing.

Primary exercises are movements, which by definition tend to yield the most profound results; whereas those further down the continuum have lesser effects, and are usually technically simpler. The examples cited above for each category are certainly not comprehensive, and it is not difficult to create hybrid movements. For example, weightlifting movements in which explosive impulse and power are the fundamental objectives represent a special case of primary exercises that are semi-ballistic in nature.

The lunge and step-up each meet the criteria for a primary exercise; whereas machines such as a hip sled or leg press arguably do not, despite the fact that they may involve similar muscle mass and exertion. In fact, the latter may be viable options during extremely intensive workloads and/or the athlete's trunk cannot safely support the weight required to train the legs in movements such as the squat or deadlift (as discussed below).

The chin-up/pull-up, dip, push-up and related exercises can be considered multi-joint weight-bearing movements, which would place them in the primary category according to this scheme. However, they often receive less emphasis than the traditional upper-body exercises mentioned above. Furthermore, they usually do not involve the same muscle mass or resistance used in other primary movements, making it difficult to justify placing them in the same group. All things considered, however, they may deserve greater consideration than "standard" upper-body movements.

There are other examples as well, but the point is that this classification scheme is not an attempt to label certain movements as being good or bad. It is simply a place to start making rational decisions about selecting and prioritizing them. As is the case with all aspects of a program, principles should be used as a guide rather than preferences. Perhaps most importantly, this means that training effect has precedence over strength demonstration. The objective is to choose the most effective movements and execute them in the most beneficial way.

## Weightlifting Variations

While sound movement mechanics are imperative, it may not be necessary in all cases to perform the classical lifts as they are done in competition. For example, the weightlifting movements can often be adapted or modified for the sake of simplicity. In any case, the following safety guidelines should be observed:

* Use bumper plates; and (at least) an 8' x 8' platform which is clear of loose plates, obstacles and people. Do not have anyone attempt to spot you.

* Technique - especially posture and explosiveness - has priority over weight at all times. Get into the "power position", and use your hips and legs to get action on the bar.

* Be prepared to miss a rep. If you lose control of the bar or can't complete a rep for any reason, quickly get out from underneath and let it drop (do not try to save it on the way down):

    o Use the barbell's downward momentum to move out of the way. Keep your grip and push yourself away from the bar as it falls.

    o Stay between the plates. This does not mean that you should remain under a falling barbell, but rather move backward or forward (not sideways) to escape.

Clean/Snatch In terms of training effect, it makes very little difference if the athlete starts from the floor or hang position; or whether he/she catches the bar. In fact, one of the simplest ways to teach these exercises to a novice athlete is to perform a high pull from the hang position (variations can include ranges from just above the knee to the upper thigh), where the bar does not descend below knee level at the start of the movement, and is not caught at its completion. Once this movement has been mastered, it can then be appropriate to progress into a pull from the floor and finally the power clean. A similar progression can be used in teaching the snatch. In either case, the success of each rep can be gauged on the athlete's ability to get into the "power position" and use the hips and legs to promote action on the bar, jumping and pulling explosively enough to separate his/her feet from the platform.

Jerk Once again, in terms of training effect it makes very little difference if the athlete performs a split when catching the bar overhead. Once the basic mechanics of this lift are mastered, however, the split can improve an experienced athlete's ability to manage the bar by achieving a lower receiving position than is otherwise possible (unless he/she has the mobility to drop into a full overhead squat). A simple progression for teaching this exercise is to begin with the push press and move to the push jerk before progressing on to the jerk. In either case, the success of each rep can be gauged on the athlete's ability to dip (6 - 8", or 10% of body height) and drive through the "power position"; and use the hips and legs to get action on the bar, jumping and pushing explosively enough to separate his/her feet from the platform.

## Powerlifting Variations

Deadlift /Squat This discussion will address some adjunct considerations for safely and effectively performing the conventional squat and deadlift. These guidelines apply generally to both movements due to their gross similarities.

Optimal range of motion in the squat or deadlift is that in which the trunk does not round or lean excessively forward, or the athlete does not feel unusual pain (to be distinguished from the discomfort of exertion). Many athletes can safely achieve the classic parallel depth position with heavy weights, but some cannot. For those who do not compete in the sports of powerlifting or weightlifting, several points should be considered when pursuing an optimal training effect.

1. Flexibility is an element of any functional movement including squats and deadlifts. Active and/or passive mobility are intrinsic to every skill or technique, no matter how simple or complex; and should thus be developed to optimal levels for two reasons. First: strength is applied through a movement path (range of motion); and an athlete's neuromuscular system generates peak power - and Second: operates most efficiently - when explosively stretch-loaded and recoiled.

2. Achievable depth often depends on the resistance being used. Even athletes who have difficulty achieving parallel with heavy and limit weights often can (and generally should, unless otherwise contraindicated) do so during submaximal/warm-up reps. Thus, the inability to achieve a predetermined depth with heavy weight does not necessarily mean that it cannot be done at all.

3. Contrived methods of keeping the hips in line with the center of gravity, moving the knees in front of it, or otherwise altering the normal execution of these movements (e.g., by elevating the heels) are counterproductive and potentially injurious. A stable base and balanced position are generally best achieved by positioning the hips, which are the stronger and more stable structure, behind the athlete's center of gravity in order to receive most of the torque (as described below); and driving through a "full foot" which is flat on the floor, with weight evenly distributed between the heel and forefoot.

4. Most importantly, the names of these (or any) movements are not as important as what they are intended to do. Form should be dictated by function. Multi-joint exercises provide an opportunity to overload the major structures of the body by putting the "power zone" (i.e. hips) in an optimal position to transmit the largest force. It follows that torque at the hips is maximized by moving them as far behind the center of gravity as possible, while flexing as far as the athlete's leverage and body position allow. Squatting or deadlifting depth can therefore be considered secondary to position. The key to a beneficial training effect is to move the hips back while sitting to an optimal depth, not necessarily to aim for any predetermined thigh angle. Depending on the athlete's body proportions, maximal torque may occur at or below an angle of ~90° at the hip and/or knee, with the midline of the thigh well above the parallel position. In the case of the squat, it is also interesting to note the effect of bar placement: The powerlifter's "low-bar" position usually allows the hips to move further backward than does the weightlifter's "high-bar" position, although this varies with individual body proportions and mechanics.

In summary, the effort required to overcome a given resistance obviously increases with depth. Beyond a certain point, however, this is the result of a loss in leverage rather than a gain in torque, in turn bringing stress-strain relationships into question. This is not meant to imply that parallel depth should be abandoned; or that the "half squat" should be universally adopted. The latter can be effective for those whose mechanics and/or flexibility do not permit them to safely get their thighs parallel according to the criteria presented above. The salient point is that a standardized depth, which originated decades ago as a means of judging powerlifting competitions may not be appropriate in all situations; and that "full range of motion" should be critically evaluated for each situation, rather than simplistically accepted as a ubiquitous rule.

Alternatives With the obvious exception of the competitive lifter, there comes a point in an advanced athlete's development when it may no longer be judicious for the trunk to support the heaviest weights that the hips and legs are capable of moving. This is not intended to dissuade athletes from performing heavy structural movements. Indeed, one of the most effective ways to strengthen a healthy trunk is to load it in a fixed position while the lower body does the work, transferring force through the segments of the body. Likewise, lack of torso strength is an underlying cause of many so-called back problems. However, it is important to realize that the human spine is a tower, which was originally designed as a bridge. One should therefore consider its limitations, and corresponding training options, when approaching advanced levels of strength.

One recommendation is to view the primary exercises as a family of ground-based movements, which are interchangeable to some extent. It is a simple matter of whether the weight is supported across the shoulders or suspended from them. If an athlete is better able to handle heavy squat weights by substituting the conventional deadlift in its place, it may be appropriate to do so because the two movements are more similar than they are different. Furthermore, if the athlete has difficulty maintaining good posture when deadlifting from a static bottom position, it may be appropriate to set the bar up on blocks or racks and descend into each rep from an upright position. In this way, the best features of each movement can be combined to achieve an optimal training effect.

Many athletes reach a point where they simply cannot maintain a flat back when venturing into very heavy squats or deadlifts. The trunk must then be unloaded and/or supported in order to train the hips and legs to their limit. One option is to progressively introduce other structural movements which do not load the trunk as heavily, such as the lunge or step-up. Another is to include assistive hip/trunk strengthening movements such as the glute-ham raise, stiff-legged deadlift, or trunk/reverse extension into the program in order to work the major structures in different combinations while unloading the torso. An additional option is to use barbell exercises for submaximal weights, and perform the heaviest sets on hip sled, leg press or other apparatus, which supports the torso. When pursuing a specific objective, the pros and cons of various alternatives should be considered.

## Balance

Imbalances are a leading cause of non-athleticism, injury and/or chronic orthopedic problems, and thus a sound program must include movements for every major muscle group. It is very possible to make big gains in strength and see little or no functional transfer if certain movements are neglected, allowing antagonistic muscle-group deficits to develop.

The concept of using power and control to achieve overload largely takes care of itself - at least during lower-body workouts - when the program consists of athletic free-weight movements. A useful rule of thumb is to include a "pulling" or flexion exercise for every "pushing" or extension one such that each movement plane is worked equally in both directions. In the case of lower-body training, primary movements can be balanced out to a large extent with exercises such as the glute-ham raise, abdominal/trunk flexion and various isolation exercises. However, this becomes more challenging in the case of upper-body training because of the mobility of the shoulder girdle and resulting need to offset traditional pressing exercises; hence the value of high/low cable stacks and various free-body exercises.

## Training Methods

A hierarchy of training methods for specialized strength development is illustrated in Table 1. As can be seen, this classification scheme is largely a matter of practicality and there is some overlap. The key to applying these methods lies in their skillful combination rather than exclusive or disproportionate use of any one of them.

Table 1: Classical Training Methods for Specialized Strength Development

### Maximum Strength

- Brief maximal efforts (intra/intermuscular coordination; rate of force development)
  - *intensity* ... 75-100%
  - *action speed* ... slow to explosive
  - *volume* ... 15-25 reps/session @ 95-100%; 20-40 reps/session @ 90-95%; 35-85 reps/session @ 80-90%; 70-110 reps/session @ 75-80% (≤8 reps/set for low skill movements; ≤3 reps/set for high skill movements)
  - *density* ... full (up to 8 min) recovery between sets
- Repeated submaximal efforts (hypertrophy)
  - *intensity* ... 80-90%
  - *action speed* ... slow to explosive
  - *volume* ... 5-10 sets per exercise
  - *density* ... 1-4 min recovery between sets; 24-48 hours between sessions
- Combination methods

### Speed-Strength

- Submaximal accelerative efforts (power; rate of force development)
  - *intensity* ... 30-85%
  - *action speed* ... explosive/maximal
  - *volume* ... 3-7 sets per exercise; 1-3 reps/set @ 85%; 3-5 reps/set @ 80-85%; 5-8 reps/set @ 70-80%; 8-15 reps/set @ <70%
  - *density* ... 2-8 min recovery between sets; daily sessions
- Reactive-ballistic efforts (stretch-shortening cycle)
- Contrast methods

### Strength-Endurance

- Extensive interval:
  - *intensity* ... 30-40%
  - *action speed* ... brisk/continuous
  - *volume* ... 3-6 sets per exercise; 20-30 reps per set
  - *density* ... <5 min recovery between sets
- Intensive interval:
  - *intensity* ... 50-60%
  - *action speed* ... explosive
  - *volume* ... 3-6 sets per exercise; 20-45 second duration per set (rep count is irrelevant)
  - *density* ... 1-3 min recovery between sets

Sources: Aján & Baroga; Fleck & Kraemer; Hartmann & Tunnemann; Lyttle; Schmidtbleicher; Siff & Verkhoshansky; Stone & O'Bryant; Zatsiorsky.

## Maximum Strength

Brief Maximal Efforts This method is intended to improve intra- and intermuscular coordination, and to minimize neuromuscular inhibition. Although a relatively narrow corridor of motor units is activated, this method likely allows high-threshold (and quickly fatigable) motor units to be recruited at their greatest discharge frequency and synchronicity. It is useful for advanced athletes, but is generally inappropriate for novices. This method tends to improve RFD and the ability to accelerate heavy loads, but has minimal hypertrophic effect (which can be advantageous in certain situations).

Repeated Submaximal Efforts This method is usually applied with various intermediate intensities and a traditional "repetition maximum" approach. It is an effective means of developing basic strength and muscle mass in novice athletes, as well as maintaining them in advanced athletes. While it can also be useful in improving high-intensity endurance performance, this response is dissociated from - and often diluted by - it's hypertrophic effect. This method targets a relatively large population of motor units, and has much less effect on PRFD or high-resistance acceleration ability (at least in highly qualified athletes). Furthermore, advanced athletes should limit its use due to the high work volumes (i.e. overtraining potential) associated with it.

## Speed-Strength

Reactive-Ballistic Efforts As previously mentioned, springlike movements involving SSC actions are characteristic to many sport activities. Ballistic "plyometric" drills are intended to develop the athlete's reactive-explosive strength by exploiting two phenomena: neuromuscular reflex potentiation and musculotendinous elastic energy recovery. Acute training responses include increased mechanical efficiency and overall "working effect" (e.g., power, impulse); whereas chronic responses involve up-regulation of muscle stiffness and motoneural activation. The basic classification scheme for SSC actions is as follows:

* Long-response ...ground contact >0.25 sec, large angular displacement (e.g., sprint start/acceleration; squat/countermovement jump).

* Short-response ...ground contact <0.25 sec, small angular displacement (e.g., maximal sprint velocity; high/long jump).

This scheme is useful in selecting plyometric drills to improve specific performance qualities. For example, long-response training tasks would tend to have the greatest transfer to the sprint start and initial acceleration; whereas short-response tasks have the greatest transfer to top speed performance.

Submaximal Accelerative Efforts Inherently impulsive movements such as olympic-style lifts, plyometrics and other reactive-ballistic actions are not the only methods for developing speed-strength. However, the role of acceleration and RFD in non-ballistic tasks is often misunderstood or neglected. These factors are especially important considerations for athletes, and are fundamental to force production even when executing basic structural exercises (indeed, note that explosive movement intent is recommended for most of the training methods itemized in Table 1). It is a simple matter of understanding the relationship between force and acceleration, and of addressing some practical considerations with respect to task and workload.

As is the case with reactive-ballistic efforts, the method of submaximal accelerative efforts is inferred from a basic physical law: Force is the product of mass and acceleration (F=m - a). Simply put, since the forces acting on an object are proportional to its acceleration, that object - regardless of mass - must be accelerated to the limits of one's ability in order to generate maximum force. As mentioned previously, successful execution of most functional tasks requires rapid force application. Non-ballistic movements, including traditional strength training exercises, are no exception; and thus in all cases range of motion can be considered an acceleration path. The only distinction is whether the object is accelerated through the sticking region, or through the entire movement in order to project it ballistically.

At first glance, this law may seem to imply that there is no force without motion or vice-versa. However, this is not necessarily the case. For example, since gravity is expressed as an acceleration constant [~9.8 m/sec-2], a vertical force of ~980 newtons [kg-m/sec-2] is required to hold a 100 kg barbell in place statically. Despite the apparent simplicity of this fact, the inability or unwillingness to grasp its functional significance is an underlying cause of many nonsensical training methods. It is a foundational principle upon which all motion is based. When considering that any movement is essentially an act of defying gravity - which itself is an accelerative force - the central issue becomes: What is being moved, and how fast?

Simply stated, the object should be moved through an optimal acceleration path within a certain time period in order to maximize impulse production and subsequent training effect. Weightlifting movements are examples of resistance exercise that are close to the high-speed end of the spectrum, whereas powerlifting movements are relatively nearer to the low-speed end. Regardless of whether one performs either type of these movements in training or competition, the salient point is the same for each: Peak force and motoneural activity (relative to one's capabilities) are only generated if the load is maximally accelerated through the "power position" or "sticking region". Aside from the obvious fact that light weights can be moved more rapidly than heavy ones - and that some tasks are inherently ballistic, while others are not - this has two other fundamental implications:

* The intent to move explosively may be as important as actual velocity achieved. Full volitional effort (i.e. a deliberate attempt to maximally accelerate the resistance, even if it is too heavy to move rapidly) yields the greatest neuromuscular activation and subsequent adaptive response. Submaximal force production and neuromuscular activation - which, by definition, are precisely what occurs when a given resistance is not accelerated to the limits of one's ability - simply don't make sense as a viable or productive means of training.

* Rate, direction and amplitude of force production are equally important (and trainable). Their brief application in certain parts of the movement is more important than sustained application over its full distance or duration. Some athletes and coaches mistakenly believe that RFD is only relevant during ballistic tasks, but not in basic exercises where the weight is not projected. As will be seen, however, this notion needs to be revised.

It is important to understand that high-speed movements are not the only way to activate - and train - FT muscle fibers. Motor units exist in a spectrum and are progressively recruited as power or force output increases. Given the range of force-velocity combinations possible in any movement, it is not surprising that the neuromuscular system activates motor units as well as muscles in functional task groups. Furthermore, force production is not just a matter of motor unit recruitment, but also of coordination and synchronization. The higher centers of the neuromuscular system, which govern this process, are as plastic as the muscle fibers themselves. Adaptation is a function of activation, and maximal effort at a given resistance is the means toward achieving it. Indeed, adaptive tissue remodeling may be an up-regulation response to innervation signals more so than a simple cellular repair process (e.g., when a FT motor nerve is grafted onto a ST muscle fiber, that fiber's properties proceed to reverse themselves).

Practically speaking, a wide range of workload intensities and volumes can be justifiably recommended. And yet despite all these options, a strength training program's effectiveness will be limited if it is approached exclusively in terms of weights and reps, while ignoring the accelerative quality of force. Likewise, it is a mistake to assume that full activation automatically occurs whenever the bar is moving; or that the last rep of a set triggers the desired training effect. These are particularly costly errors for those who abbreviate work volume to the point where they cannot afford anything less than extreme emphasis on training quality. The solution is to maximize force output and neuromuscular activity on each repetition by accelerating through the sticking region at full power, regardless of resistance or rep count.

In practical terms, it is important to consider how acceleration interacts with the sticking region, defined as that part of the movement path where leverage and resistance interact to create the greatest difficulty in moving or controlling the bar. Using the squat or deadlift as an example, the sticking point resides at a femur angle approximately 25-30° above the parallel position. As is the case with many multi-joint exercises, it comprises a small portion of the movement; but may occupy a relatively larger segment (perhaps up to 1/3 - 1/2) of the time required to execute it. During fatigued states and/or 1RM attempts the time segment of movement through the sticking region can be larger. It may be argued that because maximal effort is not required elsewhere in the movement path, the peak force generated in this sticking region can be considered the primary reason for performing these exercises in training; while arguably the lesser forces applied elsewhere in the range of motion are secondary.

The relevant point is that brief, rapid force application is characteristic to a wider range of activities than is often believed. The practical implication of this concept is straightforward, and presents a radical departure from the so-called "time under tension" theory as well as other purposefully slow training methods. Following is an example of how the method of submaximal accelerative efforts can be applied when performing basic movements like the squat (note that this approach can be adapted to other compound exercises as well):

1. Sit at a controlled speed into an optimal position; do not "free fall" into the descent.

2. Immediately accelerate out of the bottom position and continue to accelerate through the sticking region as rapidly as possible with good form.

3. Care should be taken at the top (end of the range of motion) of each rep so the bar doesn't jump off your shoulders or out of your grip.

There are two other practical issues regarding this method: deceleration at the end of the movement path, and possible breakdown of technique. First, consider that even moderately heavy weight is not easy to move rapidly despite a deliberate attempt to do so. Furthermore, if the athlete backs off from maximal acceleration toward the top of the ascent, gravity will decelerate the bar's vertical velocity. In any case, if it is still moving upward by virtue of its own momentum upon reaching full extension, there are two options:

* The athlete is accelerating the weight beyond the sticking point, and should adjust his/her effort during the latter 1/3 - 1/2 of each rep in order to avoid "jamming" it at the top.

* The chosen resistance is so light that the athlete would do better to perform a ballistic exercise with equipment designed to be launched explosively.

Second, technique need not be sacrificed for impulse or power; whereas form often does degrade to some extent during very heavy, slow lifts. If we were incapable of achieving a reasonable degree of technical precision whenever we accelerated above first or second gear, it would be impossible to execute simple acts of running, jumping, throwing or other functional tasks. Conversely, this method should not be misinterpreted to suggest that barbells and dumbbells are to be yanked on and hurled recklessly around the weightroom. The point is simply that anyone with enough common sense and motor coordination to properly perform basic exercises should be able to maintain control when applying this method. If anything, it actually allows the athlete to stay in the groove through the sticking region where the bar otherwise tends to drift off course.

Contrast Methods This approach is intended to exploit the after-effect of preceding work to increase the efficacy of subsequent work in a single training session. An example would be to "complex" explosive-reactive efforts with brief maximal efforts in order to activate the athlete's neuromuscular system in alternating but complementary ways. This is an advanced strategy which capitalizes on the acute residual effect of certain work regimes in much the same way that cyclic, long-term workload variation improves adaptive responses by exploiting their cumulative and delayed effects. It should be conducted with optimal rest intervals and minimal fatigue, and is generally inappropriate for novice athletes.

## Strength-Endurance

Extensive & Intensive Intervals These methods are intended to improve endurance capacity during prolonged low-intensity and brief high-intensity workloads, respectively; and also to improve subsequent recovery ability. Both approaches (especially the former) involve comparatively large work volumes. The latter may at first appear similar to the method of repeated submaximal efforts, but tends not to yield the same hypertrophic effect.

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