BIOMECHANICS OF THE SNATCH: TOWARDS A HIGHER TRAINING EFFICIENCY

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Athletes in strength and power sports such as American football, weightlifting, and track & field events use various types of power and speed/strength exercises in their training. The snatch and its variations are useful training exercises for these athletes. There are several variations of the snatch, for example:

- squat snatch (used in weightlifting competition).
- power snatch.
- split snatch.
- snatch from kneeling position (bending and extending hip joints and putting one leg In front).
- snatch from hang.
- snatch from blocks (using different heights).
- one-legged snatch.
- various pulling movements (e.g. with weights or dumbbells).

It is Important to understand the biomechanics of the snatch. Biomechanical and technical knowledge of both competition and training exercises can help one select the appropriate exercises to train for various sports. Variations in the snatch (which differ from the squat snatch used in competition) can alter movement patterns and barbell velocity, resulting in different specific adaptations. For example, many sports require a high power output from the hip and knee extensor at the same time. Thus, snatching from the hang position can be advantageous in that It forces the hip and knee extensors to work in unison.

The coach is fundamentally concerned with guiding the adaptation process toward the demands of performance, or competition. Because the specificity of the exercises used in competition dictate the structure of the training process, a good understanding of biomechanics will help the coach guide the athlete toward greater training efficiency.

The external movement pattern of the snatch is described by Derwin (5), Garhammer and Takano (6), and Takano (11). Figure 1 shows the movement path of the barbell with the corresponding body positions at different points in time for two lifters. In the first pull (see Positions 1-3) the knees and hips are extended, ankles are plantar-flexed, feet are in complete contact with the floor, and the trunk is held almost constant to make for an effective force transition.

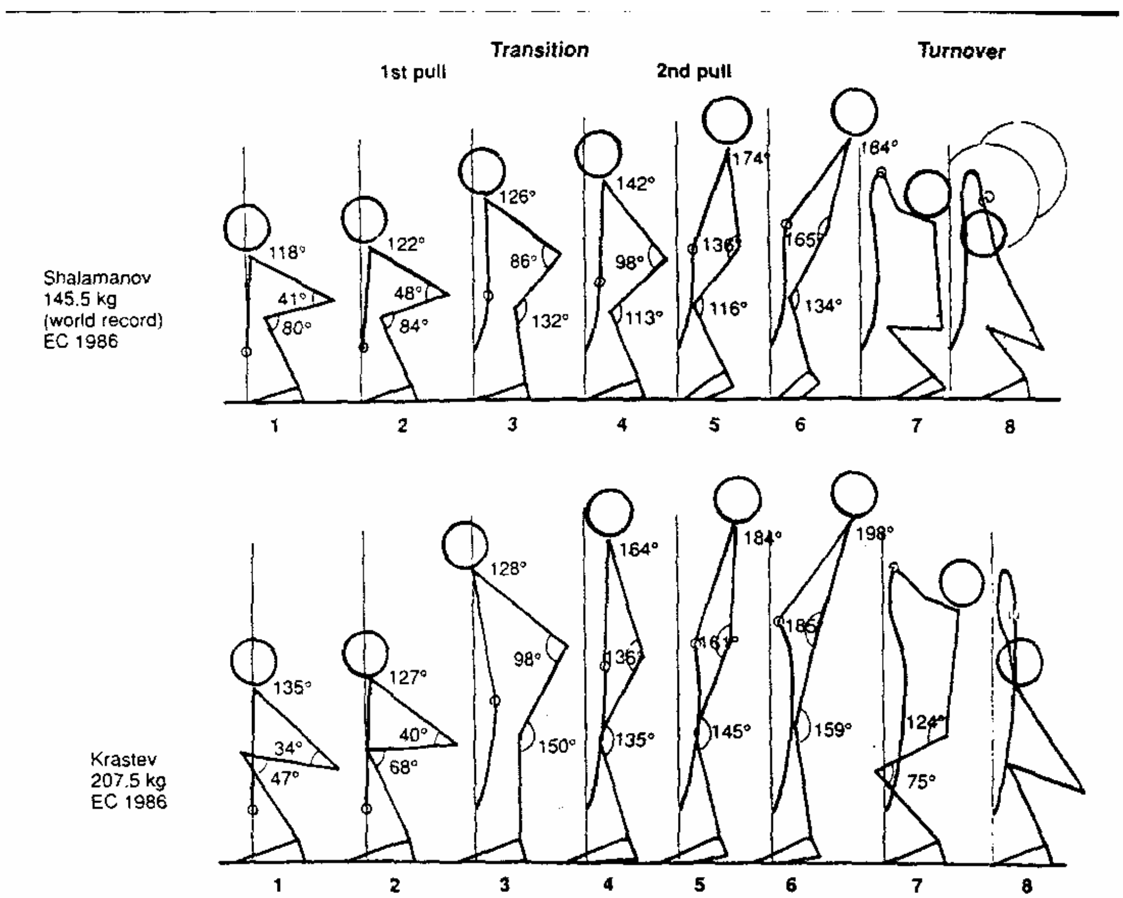

Figure 1 **Body positions during the snatch and path of the barbell (12) for 2 lifters of different weight categories. Note that the working conditions for the main muscle groups of the legs differ for each lifter as a result of differences in body dimensions.**

The working area for the knee and hip extensors can differ depending on the size of the athlete. Taller athletes start with more bending of the knees, as shown in Position 1 of the bottom example in Figure 1. The shorter athlete begins the first pull from a knee angle of 80° whereas the taller athlete bends the knees to an angle of 47°. At the end of the first pull the bar reaches about 80% of its maximum velocity.

In the transition from the first to the second pull, shown in Positions 3 and 4 of Figure 1, the knees are pushed toward the bar and the knee angle is decreased about 20°. By helping the lifter ease into the second pulling phase while continuing to extend the hips, this action, when performed correctly, results in a barbell movement without any decrease in velocity.

The second pull, shown in Positions 4-6 of Figure 1, follows with a smooth transition to the powerful ankle plantar-flexion (raising the heels), knee, and hip extension. Ankle work can contribute up to 10% of maximum bar velocity (12). At the end of the extention phase of these joints, the weight reaches maximum velocity. The slight lifting from the floor initiates a repositioning of the body.

Positions 6—8 of Figure 1 show the turnover and catch. During the upward movement and beginning of the barbell’s downward movement, the lifter must move his or her body downward and, with feet completely in contact with the floor once again, decelerate the downward movement of the barbell. The arms should be locked at the conclusion of the catch phase.

The differences in the trajectory in Figure 1 are the result of differences in barbell velocity. The shorter lifter shifts the bar (vertical displacement) about 72% of the distance utilized by the taller lifter. Therefore differences in the necessary bar velocity are inevitable. Athletes of the 52-kg category need 1.50-1.60 m/s. By comparison, athletes of the super-heavyweight category need 1.90-2.00 m/s (9).

Movement of the Barbell

A perfect coordination of the separate movements ensures that the trajectory of the weight remains behind the vertical line at all times, as shown in Position 8 in Figure 1 and also in Figure 2b. By training the muscle snatch (catching the bar overhead while only slightly bending the knees) or high pull exercises, the lifter will, in the second phase, move the weight slightly in front of the vertical line. Barbell trajectory will be ineffective if hip extension is too rapid in the first pull or if arm / trunk angle is too great in the second pull.

The velocity of the bar should increase continuously. A short velocity plateau between the first and second pull is acceptable. Figure 2b shows a flowing transition from the first to the second pull. A movement coordination that results in a continuously increasing bar velocity is mechanically effective because the lifter only transfers a minimum of physical work to reach a given velocity.

There is often a dip in the velocity vs. time relationship between the first and second pull (see Figure 2a and Figure 3). The short decrease in velocity requires a higher level of ability for the second pull. For the snatch performance shown in Figure 3, athlete “M” must overcome the additional decelerating impetus of -55.5N · s (185 kg x -0.3 m/s), or about 16% of the total impetus (185 kg x 1.9 m/s

= 351.5 N · s). Too fast of a first pull hinders the transition phase. The after-effect will be a noted decrease in velocity.

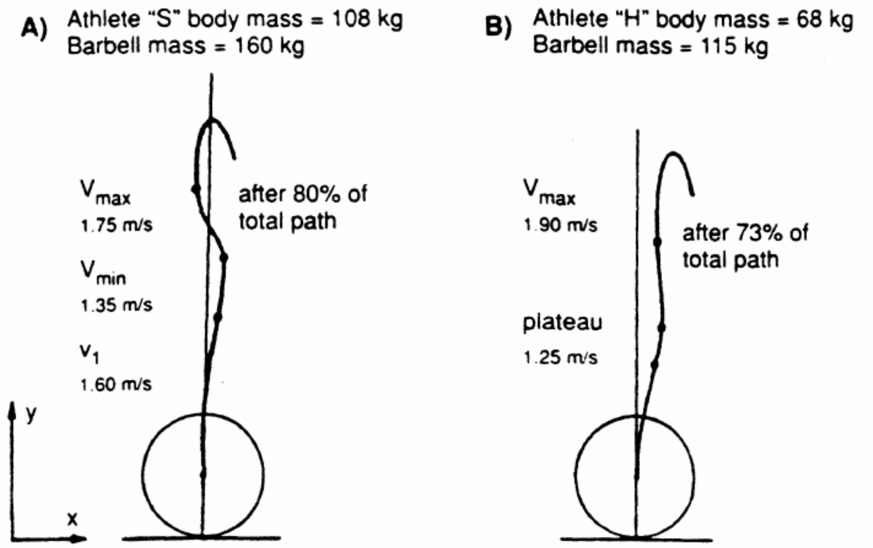

Figure 2 **Movement path of the barball and related velocity values. Athlete "S" lifted 1.5 × BW while Athlete "H" lifted 1.7 × BW. Athlete "S" had a rapid first pull: 91% of max velocity vs. 66% for Athlete "H."**

Research by Martjanov and Popov (10) has revealed there is great variability in velocity changes for successful lifts, as can be noted in the area between the dashed lines in Figure 3. It appears that a prerequisite for movement stability during weightlifting competition is a corresponding stable movement execution of the main training exercises (e.g. velocity vs. time. characteristics). But such zones hardly contain feedback about the effectiveness of the movement pattern (compare the performances of "M" and "N" in Figure 3). The movement pattern requiring less energy that of Athlete in Figure 3, is more effective.

Note that a slight decrease in velocity during the transition phase, as a result of knee movement toward the bar, hypothetically can create higher muscular pretension of the quadriceps muscle group for the second pull. This is illustrated in Figure 1 in the decrease of knee angle between Positions 3 and 4 of both lifters. Therefore a final assessment of the lifting technique must consider the general mechanical and physiological effects along with the lifter's skills and abilities.

Maximum velocity of the barbell is an important factor in ensuring that the training load is applicable to the weight used. The product of maximum velocity (V_{max}) and weight (m · g) presents the "external" (measured on the barbell) physical power component for the vertical barbell lift at this critical time. This parameter is called speed-strength power ($P_{s\text{-}s}$):

$$m \times g \times v_{max} = P_{s\text{-}s}$$

$$(kg \times m/s^2 \times m / s = W)$$

Note that the total power contains a component for barbell acceleration as well. The value of this component is fairly low compared to the lift component. Because power is the work (energy) performed in a given time period, the relationship between the work required to accelerate and to hit the barbell expresses the relationship between the power components:

Kinetic energy

$$m/2 \times V_{max}^2$$

Potential energy

$$m \times g \times h$$

where m = barbell mass; V_{max} = maximum barbell velocity; g = 9.81 m/s^2: h = path of vertical barbell lift.

The following example illustrates this relationship (barbell mass = 100 kg, maximum velocity = 2.0 m/s, vertical lift path = 1.25 m):

Kinetic energy

$$100\ kg/2 \times 2^2 m/s = 200\ N \cdot m$$

Potential energy

$$100\ kg \times 9.81\ m/s^2 \times 1.25\ m = 1226.3\ N \cdot m$$

The lift component of the work is about six times greater than the acceleration component. The relationship between the power components are comparable to the work relationship. In several European countries, the parameter of speed-strength power is used late in the strength training of weightlifters, throwers, and sprinters (1).

Real data points to the importance of speed-strength power in planning the training regimen. The example shown in Figure 4 is taken from Bartonietz and Borkeloh (3). The athlete, who was Olympic champion in 1992 and world champion in 1995, snatched 180 kg with a maximum velocity of 1.93 m/s ($P_{s\text{-}s}$ = 3.40 kW) and 190 kg with a maximum velocity of 1.83 m/s (P = 3.42 kW). His personal target velocity was 1.83 m/s. He could snatch a weight >190 kg if he could accelerate the 190 kg up to the 1.83 m/s level. A training load of 170 kg must be lifted with a velocity of 2.04 m/s ($170\ kg \cdot 9.81\ m/s^2 \cdot 2.04\ m/s = 3.40$ kW) for a maximum training intensity. In 1988 this athlete snatched a personal best of 200.0 kg., and at the 1992 Olympics he snatched 192.5 kg.

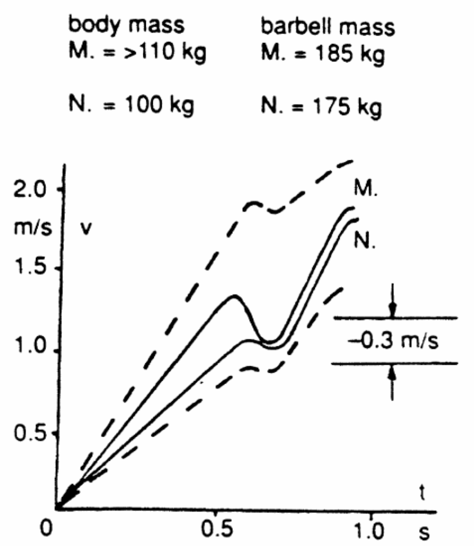

Figure 3 **Acceptable variations of barbell velocity of the snatch (dashed lines) and velocity vs. time data of 2 performances (10). The dashed lines mark the extremes of all valid attempts for these lifters.**

The goal of training must be higher power values, for example using high pulls. The relationship of velocity vs. barbell mass for high pulls, demonstrated in Figure 4, shows that speed-strength power is greater than the 4-kW level over the whole tested interval (192.5 - 222.5 kg. A competition result of 207.5 kg would require a $P_{s\text{-}s}$ level of 3.77 kW. This power level could be developed with high pulls because they make greater demands on power.

In addition to the four ways of estimating exercise intensity - magnitude of resistance, number of repetitions per set, number of repetitions with maximal weight, workout density (13) - the product of weight and velocity is another important factor.

It appears that young athletes should stress movement ***velocity*** rather than weight, along with proper technique. Only in the later stages of athletic development do weight increases become the most important factor. Some training experiments have shown that power abilities (e.g. for throwers) can be developed through weight training as well as through speed of movement execution (4.7).

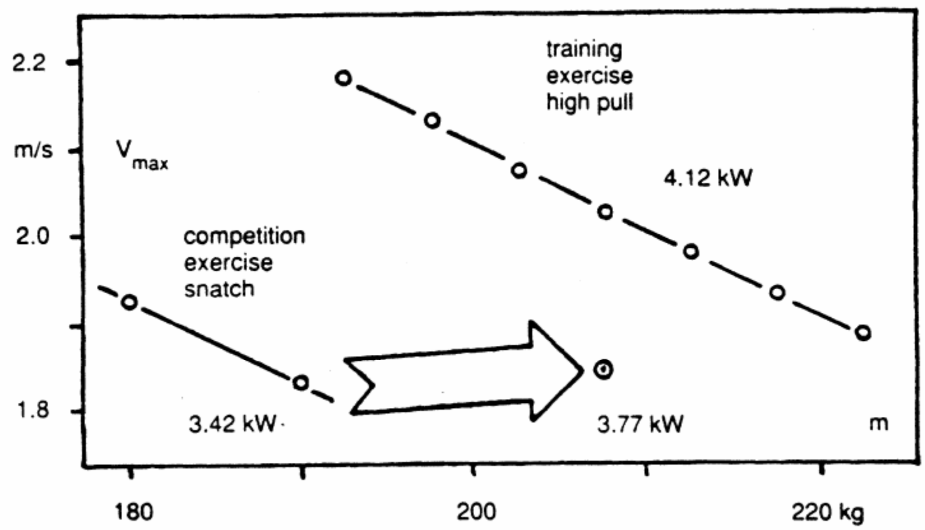

Figure 4 **Relationship between barbell mass and maximum velocity for a lifter in the snatch and high pulls (3). Note that snatching 180–190 kg as fast as possible requires a speed-strength power of 3.42 kW, while high pulls demand more than 4 kW over the entire weight range if they are to be executed at maximum velocity.**

Once the maximum velocity of the barbell is reached and there is no further accelerating force on the bar, the remaining path of the weight, which is the distance ***s***, will be determined by the following equation:

$$s = v^2_{max} / 2 g$$

For v_{max} = 1.6 m/s, distance would be a barbell path result of 0.13 m; for V_{max} = 1.9 m/s. distance would be a barbell path result of 0.18 m.

It is not enough to turn over and catch the barbell. The intensive shrug of arms and shoulders must act against the deceleration of the barbell. The lifter needs to extend the upward path of the bar. It is possible to lengthen the path interval of about 0.10 - 0.15 m during the non-support phase in this way. This is the result of a redistribution of the lifter's and barbell's partial impetus, since the total impetus of the "lifter/barbell" system cannot be changed during the non-support phase. Catching the barbell overhead requires a fast turnover movement in order to minimize the barbell's drop velocity, which can reach 2.5 m/s by falling about 0.32m.

Limb Movements

Research in applied biomechanics is conducted to gain insight into the internal structure of the exercises. Thus it is necessary to analyze the movement of the weight, together with the limb movements around the main joints, in order to assess the work of the main muscle groups.

The power is characterized by the conversion of physical work at given time intervals and deter- mines the level of the joint moments and the external forces. Because the power of the joint propulsions can also be calculated as the product of muscle force moment and angular velocity, the time related changes of angular velocity are one way to judge the effectiveness of the movement (see Figure 5). The power of the joint drives is the most important performance-limiting parameter.

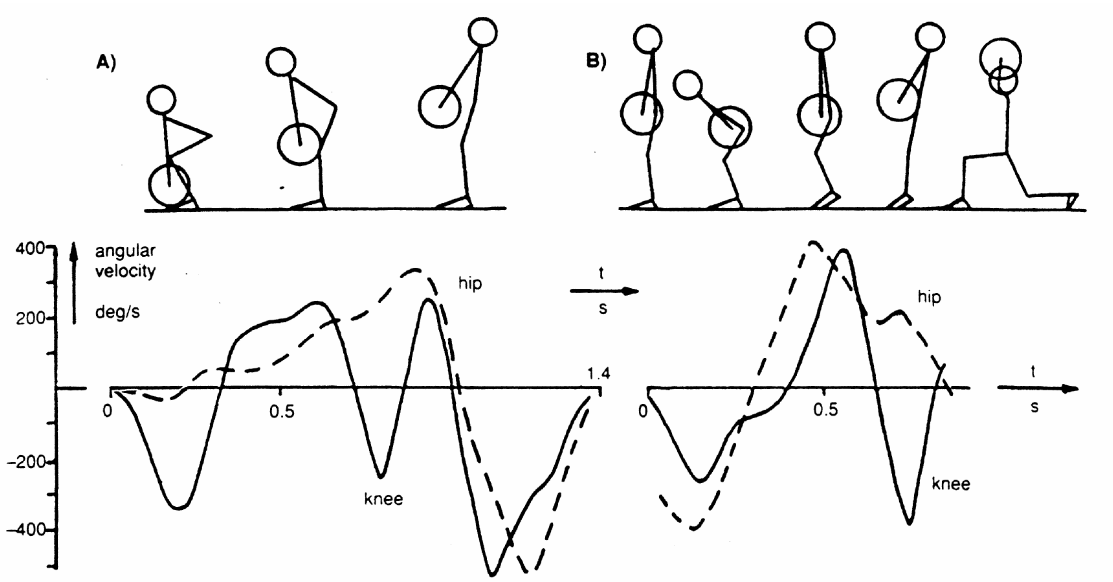

Figure 5 **Angular velocity vs. time. (A) Squat snatch at 152.5 kg, world-class weightlifter and European champion in 1986, body mass of 67.5 kg (from Ref. 12); (B) Snatch from hang at 95 kg, female world-class javelin thrower and Olympic silver medalist in 1992, body mass of 75 kg (from Ref. 1).**

In the snatch, the hip extensors must produce the highest power demands (see Table 1). The hip extensors play a major role in the whole limb chain. Without sufficient hip power, the knee extensors would have to do more work. The result could be ‘too fast of a starting movement in the first pull and a decrease of bar velocity between the first and second pull. It is recommended that there be a smooth transition to prevent an overloading of single muscles, tendons, and joints structures. Hip power reaches its maximum value at the end of the transition phase (12). Given that skills and abilities are virtually inseparable, the training must be directed toward these two sides of one complete movement phenomenon.

These data show that the “external” power of the barbell movement gives general feedback on all the internal efforts from the ankles up to the wrists. The power demands in the respective joints, especially the hips, are much larger than the resulting lift power component on the barbell (e.g., snatching 207.5 kg with about 2 m/s: $P_{s\text{-}s} = 207.5\ kg \cdot 2\ m/s \cdot 9.81\ m/s^2$ 4.071 kW can be calculate on the bar).

Some coaches believe the ankle does not have a significant influence on performance. A marked plantar flexion of the ankle is viewed as incorrect technique. Yet many world class weightlifters demonstrate an active plantar flexion of the ankles. In fact the active opening of the ankles during the second pull is essential to the vertical acceleration of the barbell and contributes about 10% of the maximum velocity (12). According to the data in Table 1, the plantar flexors of the ankles show the largest moments of all the joints involved in the movement, and their maximum power is only 10% lower than the power demands for the knees.

Snatch Exercises

The training of maximum strength abilities must be as effective as possible if athletes of different sports wish to avoid undesirable training effects. Therefore elite athletes and their coaches must find the best ways to execute specific variations of the snatch as well as other strength and power training exercises.

Younger athletes need a basic overall strength preparation. Measures for a progressive specificity in strength and power training become increasingly important in the later stages of training for top athletes because this is when they will be able to tolerate such specific and high loads.

The snatch from the hang, shown In Figures 5b and 6b, is characterized by a simultaneous explosive knee and hip extension, starting with a knee angle approaching competition demands such as in track and field events. Joint power reaches higher levels in the snatch from hang, compared with the classical snatch in which the lifter accelerates the barbell from the floor on a longer path. and therefore in a longer time period (compare the time data in Figure 6a and 6b), but lifting approximately the same weight.

The split snatch is applicable to baseball pitching and javelin and discus throwing, which all call for effective bracing of the front leg. Turnover into a split step on the bracing front leg imposes a specific load (see Figures 5 and 6). Athletes of contact sports should switch the position of their legs from time to time (i.e., left leg in front, then right leg in front). The same applies to sports such as tennis and should be adequate to the leg work for the forehand and backhand stroke.

The squat snatch is applicable to sports that demand simultaneous work of both legs, as in weightlifting, rowing, ski jumping, surfing, and volleyball.

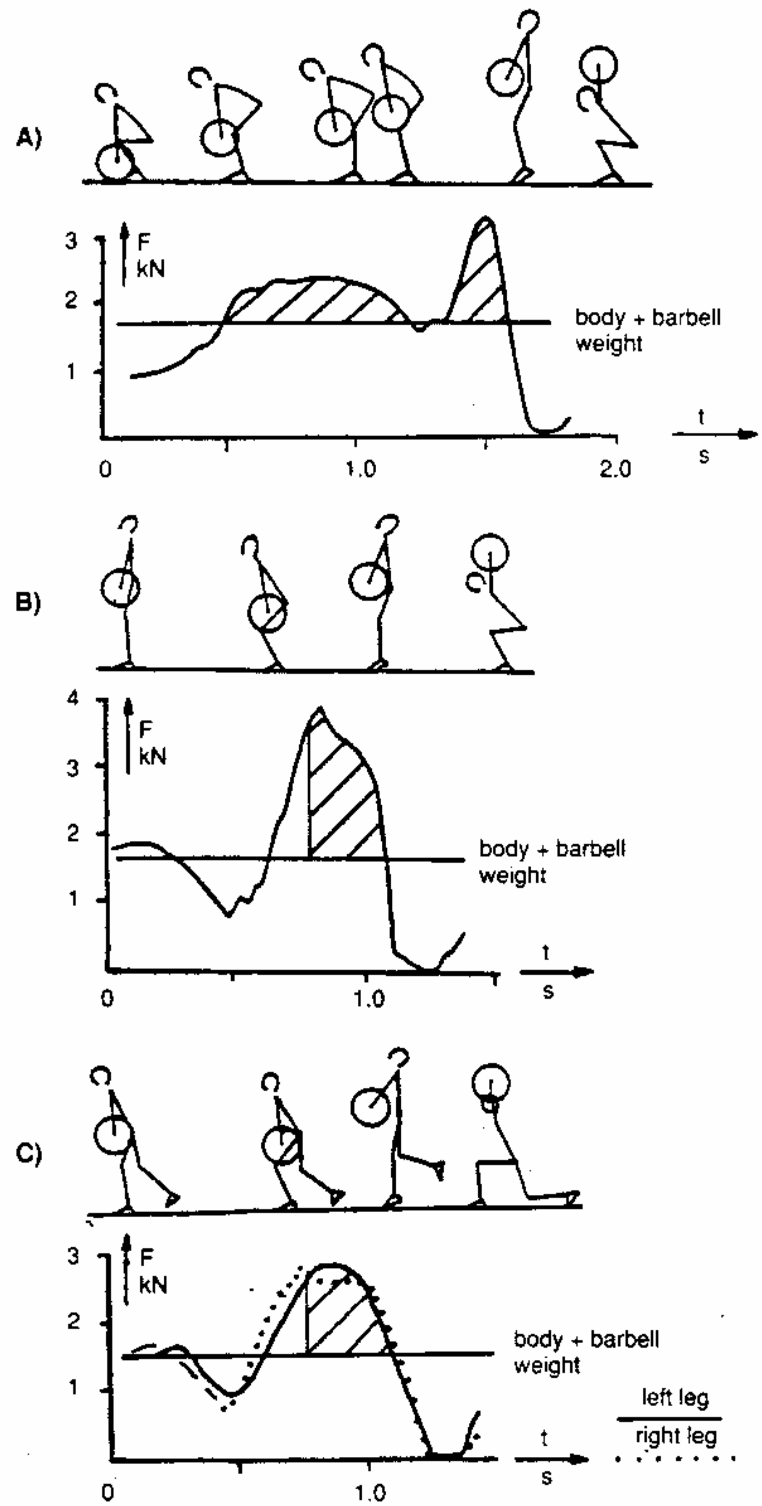

Figure 6 **Vertical component of ground reaction forces vs. time of the snatch and its variations in a decathlete (2). The accelerating impetus of each exercise is shown in hachures: (A) two-legged squat snatch from floor, 80 kg; (B) two-legged snatch from hang, 85 kg; (C) one-legged snatch with right and left leg, 65 kg.**

The high pull is applicable to throwing the hammer or heavy weights, wherein the acceleration phases during the turns finish at shoulder level. Therefore snatching the weight above this level creates an unspecific adaptation. The same concerns apply to rowing and Alpine skiing. The training weight, and therefore the load, can be higher than when executing the complete snatch movement (for weightlifters see the data in Figure 4).

Table 1:
Influence of Barbell Mass on Max Values of Joint Moments and Joint Power

Barbell Mass	Ankle	Knee	Hip	Shoulder
Joint Moments (kN · m)				
207.5 kg	3.825	3.201	3.632	3.601
227.5 kg	4.095	3.456	3.919	3.944
Joint Power (kW)				
207.5 kg	5.6	6.1	21.1	7.8
227.5 kg	6.0	6.6	23.0	8.6

Note: taken from Ref. 12

To develop unilateral explosive leg work (e.g., javelin throw, baseball pitch, contact sports, sprinting, one-legged jumps, American football), the use of single-legged exercises is a good strength training preparation. This variation sets higher loads for the one leg compared to the two legged variant because the athlete can do more with one leg than 50% of the two-legged 1-RM (compare the data in Figure 6b and 6c). This is based on differences in the movement coordination of the central nervous system between double and single-legged movements (8). Figure 6c illustrates how this exercise is executed.

Recommendations

To achieve more efficiency in training, the following is recommended:

- Draw the movement path of the bar on the monitor using a frame-by-frame playback of the videotape. From the chain link, try to determine what makes the bar move in front of the vertical plane.

- Through video analysis, try to determine the target bar velocity needed to lift one’s personal maximum weight.

- Calculate the lift power at the moment of maximum barbell velocity ($v_{max} \cdot m \cdot g$) and compare those values for different weights and exercises. A *decrease of weight* for a given exercise (e.g., snatch, clean & jerk, squat) should be accompanied by an *increase of velocity* to conserve the same power level and therefore to ensure high training intensity.

From a biomechanical point of view, the effective variant of barbell acceleration is characterized by a velocity vs. time relationship of the barbell in which barbell velocity increases continuously between the first and second pull. Even elite weightlifters sometimes show a dip in velocity, possibly due to too fast of a starting movement or to hip extensors that are too weak. Fatigue can also cause a decrease in barbell velocity during the transition phase; training measures to address this include single reps and longer rest intervals between the reps.

The performance level of the muscle groups extending the main joints and accelerating the weight must be in the right balance. The power capacity of the hip extensors is the major factor. Tests of muscle performance, such as with the help of iso-kinetic machines, can lend some insight into the relationship between hip and knee extensor power. Consider that the work of the ankle (plantar-flexion) during the second pull can add about 10% to barbell velocity.

To maximize desirable training effects, the training exercises must have something in common with the technical demands of the competition movement. Therefore try to create specific conditions for executing the movement of the main training exercises.

For sports in which weight training is used to develop maximum power, the training volume with heavy resistance exercises should not go beyond the necessary minimum. A yearly increase of performance in weightlifting exercises of no more than 5 to 10% is a proper goal in long-term development. Athletes should avoid disparities between the special performance exercises and the main weight exercises.

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