Selecting the appropriate exercises and loads for speed-strength development.

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Abstract: The ability to apply force rapidly has sometimes been labeled speed-strength. In actual dynamic muscle performance the correct definition should be power (speed X strength). This paper looks briefly at a portion of the research that has given rise to the debate between which exercises and loads are most effective for power or speed-strength development. Mechanical power output can be used as an objective criterion for selecting the most appropriate exercises and loads. Research suggests that exercises taken from olympic style weightlifting are associated with the highest power outputs. However other exercises such as jump squats are also associated with very high power outputs. Traditional strength training exercises such as squats, deadlifts and bench presses are associated with much lower power outputs. For all exercises the highest intensity loads are never associated with the highest power outputs. The submaximal loads that bring about the highest power outputs may vary, principally upon the nature of the exercise. This loading may be 80-90%, 40-60% and 30-40% 1 RM for olympic lifts, traditional strength exercises and jump squats, respectively. The use of contrasting exercises and loads within a training session has been used extensively to improve speed-strength measures.

In sports performance the ability to apply force quickly would appear a most desirable attribute for many sports. This ability, often labeled as speed-strength, requires the selection of appropriate exercises and loads for its optimal development. The purpose of this paper is to firstly briefly examine the definition and research surrounding speed-strength and consequently the exercises and loads that may be deemed most appropriate for its development.

Strength can be defined as the ability to exert force. Speed is universally defined as (distance/time). Therefore speed-strength should be seen as a combination of these two definitions i.e. the ability to apply force through a distance divided by the time of force application. Essentially this definition (force x distance)/time is the definition of power. Consequently when talking of speed-strength the actual mechanical quality being discussed is power.

Therefore power is the result of any given dynamic muscular action. However it should be seen that power is a multifaceted quality depending upon the exact contribution of the factors that constitute it. Thus power may differentiated by high force, low speed characteristics or conversely by low force, high speed characteristics. However much research propagating the use of certain exercises and intensities/loads has failed to recognize this fact.

The conflict of high loads vs low loads.

There would appear to be a conflict between which loads produce the greatest improvements in speed-strength or power to use its correct mechanical name (Young, 1992). One school of thought would suggest that the highest intensity, low speed loads produce the greatest speed-strength improvements, as compared to lighter, faster training or medium speed training (Schmidtbleicher & Bhuerle,1987). It was rationalized that the theory of orderly recruitment of motor units (Henneman et al., 1965), whereby the strongest, faster twitching motor units are not recruited unless near maximal loads are used, would account for the superiority of this high load methodology (Schmidtbleicher & Bhuerle, 1987). However other studies that compared maximal or very high force, low speed training with lower force, higher speed training have reported dissimilar results, favouring the lighter, higher speed loads (Berger, 1963; Hakkinen & Komi, 1985a; 1985b; Wilson et al., 1993).

The apparent anomalous nature of these results can be rationalized when one critically analyzes the methodology of the exercises and loads used in the research. Firstly and most importantly, Schmidtbleicher & Bhuerle (1987) used an isolated isometric elbow extension movement in assessing their subjects. Consequently power was not assessed as no movement took place. Most importantly isometric and dynamic muscle actions are clearly different physiological and mechanical phenomena (Baker et al.,1994a). The neural patterning that occurs during an isometric contraction can be expected to be clearly different from a dynamic contraction (Caldwell et al., 1993; Nakazawa et al., 1993; Baker et al., 1994a). Whilst the orderly recruitment of motor units, with high intensity contractions favouring fast twitch recruitment has been found to exist in fixed isometric contractions it may be invalid for free postural or dynamic movements (Persons, 1974). Furthermore rapid or ballistic movements bring about a preferential recruitment of fast twitch motor units, also invalidating the orderly recruitment theory (Miller et al., 1981; Nardone et al.,1989).

Thus the research of Schmidtbleicher & Bhuerle (1987) is based primarily upon the isometric testing of musculature, which is invalid for extrapolation to dynamic actions (Baker et al.,1994a). A "superior" neural pattern (Eg. decreased time to peak electrical activity of the motor units) occurring during an isometric contraction does not mean that this will occur during a dynamic contraction. It would be imprudent to base the training of large multi-joint, multi-faceted dynamic strength training exercises (Eg. power clean, full squats) upon the research that utilized fixed unilateral dynamic elbow extensions and assessed neural patterns during fixed isometric elbow extension.

Where research has assessed performance dynamically, such as in jumping performance, then loading characterized as high speed, low to medium external resistances has produced superior results (Berger, 1963; Hakkinen & Komi, 1985a; 1985b; Wilson et al., 1994). However a more holistic approach could be considered, given that a particular sport performance may be characterised by varying degrees of speed or external resistances to be overcome. For example, in either rugby league or union there are situations where speed-strength may be characterized by high speed, low external resistances (kicking the ball), high speed, high external resistances (accelerating the body mass) or low speed, high external resistances such as in tackling or scrummaging. Thus the unique characteristics of a number of sports would tend to demand that the ability to apply force not be constrained within certain levels of strength or time spans. Consequently a number of exercises or loads may need to be considered for achieving power across a spectrum of speeds and external resistances.

The remainder of this paper will address the issue of, and provide a rationale for, the most appropriate exercises and loads for power development. It will assume that the periodization of speed-strength has followed a periodization pattern whereby the maximal strength phase has preceded or is partially combined with the phase for the development of speed-strength. In these situations the strength factor of the equation has already been sufficiently developed and the conversion of strength to power must take place.

Choice of exercise

In strength training exercises, the power output can be assessed by the equation of (Mass x Gravity x Height)/Time (Garhammer, 1994). Consequently the power potential of any exercise can be calculated when the mass of the barbell plus lifter, the vertical height of the lift and the time for the lift are known (gravity being a known constant of 9.81 m/s/s). When attempting to develop a program to develop speed-strength an analysis of these factors can allow the strength coach to make objective decisions concerning the worth of an exercise in a power phase of training.

For example, it is a misconception to consider the competitive lifting sport of powerlifting (maximum full squat, bench press and deadlift) as the most appropriate vehicle for power development (Garhammer, 1994). The figures for power production from elite lifters displayed in Table 1 illustrate the potential for human power production during both competitive power- and weightlifting. It is obvious that elements of the pull in weightlifting (the top pull) and the jerk result in the highest recorded power outputs during strength training exercises. The powerlifting movements are not very powerful, despite heavier weights being lifted, in comparison to weightlifting movements. Athletes and coaches should not confuse the name with the result. The sport of powerlifting is a sport of maximal strength lifting performed at typically low speeds (although the lifter attempts to lift as explosively as possible) (Wilks, 1994) that results in low power production despite the large magnitude of the external resistances.

Whilst Table 1 reveals the power output generated by elite lifters, the power output generated by less experienced lifters is considerably reduced in comparison. For example the power output for the full squat illustrated in Table 1 was calculated during a world record 420 kg squat (Garhammer & McLaughlin, 1980). A typical strength trained male may squat 140 kg at a body mass of 75 kg (Baker et al., 1994a). Therefore the effect of the differences in mass lifted must be considered for subjects of a vastly lower level to the world championship lifters depicted in Table 1. Table 2 depicts the power that can be calculated using the equation for a theoretical athlete performing some of the standard strength training exercises. The time frames for execution of the exercises and the distance the system (barbell plus lifter) centre of gravity moves through are normative figures taken from the listed references. Clearly the three competitive powerlifts compare poorly in the production of power as compared to other exercises. As would be reasonably expected the exercises that are characterised by high loads lifted through a large distance in a short time, result in the greatest power production. Ostensibly these are the lifts derived from Olympic style weightlifting. Thus it could appear justified to warrant a greater inclusion of these lifts or their similar derivatives into the lifting phase that is aimed to convert strength to power .

However these olympic style weightlifting exercises are exceedingly complex to teach and master and their benefits may not be as readily apparent as other exercises that new technologies have made a more plausible alternative. The power produced during jump squats or push/bench press throws can actually exceed that of the olympic weightlifitng movements for lower level athletes.

Poprawski reports that elite shotputters may develop over 3500 watts (32.9 w/kg) during jump squats, a similar power output to some of the elite lifters during the pull in the olympic lifts. Hakkinen & Komi (1985a; 1985b) trained subjects for 24 weeks with either a maximal strength, high load method (70-100% 1RM plus supra maximal eccentric training) or an explosive speed-strength method characterized by medium intensity loads (10-60% 1RM). Speed-strength was measured as the power output during loaded jump squats with various loads. Their results illustrated that the maximal power output during a loaded jump squat could equate to 2086 w (27 w/kg) and

1910 w (24 w/kg), for the two groups respectively, after the extensive training period. These power outputs compare favourably with those of the olympic lifts for subjects of lower strength levels. Consequently such training and the use of the Plyopower training device or conversely a "smith machine" linked to timing mats or lights and the appropriate software to calculate power, has proven to enable even low skill athletes the opportunity to develop the power that has traditionally eluded them for 2-3 years (till they mastered the technique of the olympic lifts). Table 3 depicts the power output, calculated by the Record Time software (SciFit, Lismore), produced during a single and multiple repetition set of jump squats for some elite athletes as well as the data from Hakkinen & Komi (1985a; 1985b) and Poprawski (1987). The single repetition jump squat compares favourably with the theoretical norms for various olympic weightlifting style exercises depicted in Table 2. For example, the relative power (power/body mass) for the olympic style weightlifting movements in Table 2 is equivalent to 22.9 w/kg for the theoretical athlete of 75 kg. A single jump squat with a light load of 30 kg could achieve a relative power output of 16.3 w/kg, based upon the results of the elite development rugby players in Table 3 after only 6 weeks of specific power training. The explosively trained athletes from Hakkinen & Komi (1985b) were able to generate up to 27 w/kg during a jump squat with 40 kg upon the shoulders after six months of such power training. The multiple repetition jump squats are associated with power outputs usually only generated by elite weightlifters during the second pull or jerk thrust (see Table 1). This is not unexpected as the second pull and jumping have been shown to be biomechanically similar and result in similar ground reaction forces, irrespective of the external resistances to be overcome (Garhammer & Gregor, 1992). Consequently multiple repetition jump squats may provide an excellent alterative or supplement to the traditional olympic weightlifting style movements for the development of speed-strength. In fact Hakkinen et al.

(1986) have observed that not only do jump squats with 100-140 kg correlate highly with the maximal strength measured during a clean & jerk or snatch (r = .74 - .79), but more importantly the change in performance during the jump squats with such loads accounts for a significant portion of the change in strength in both the olympic lifts (r = . 59 - .65) (Hakkinen et al., 1987). Thus the ability to apply force quickly against large external loads appears somewhat interrelated.

The major benefit of jump squats and similar exercises would appear to be the high power output developed with relatively low loads, the easier technique to master or teach and virtual immediate improvement. With olympic style lifting a certain period must be spent perfecting technique before loads that optimize power development can be handled safely and hence improvements in power are not as readily observable. However it would also appear that the olympic lifts may allow for the most powerful execution in advanced lifters if the power produced during one repetition or portion of a repetition is the only consideration.

Strength coaches may consider the following points when selecting exercises to develop speed-strength. The lifting exercises and their derivatives from the sport of olympic style weight lifting have the potential for the highest power outputs. However exercises such as jump squats and push/bench press throws also offer a rewarding alternative/supplement. The more traditional exercises such as squats and bench press appear not be as productive in terms of power output, however their use is still warranted for developing and/or maintaining maximal strength. Power will be limited if the maximal strength component of the equation is not developed (Wilson, 1993).

Consequently a continuum of exercises for power development appears as a logical method for selecting the most appropriate exercises. Firstly select exercises that train the strength portion of the equation of speed-strength. As maximal strength is highly correlated with the cross-sectional area of the muscle (r= .95, Ryushi et al., 1988) and changes in strength with changes in lean body mass (r = .81, Baker et al., 1994b) it is of importance that the initial strength training period is aimed at increasing the hypertrophy of the muscle. Appropriate exercises would be the basic strength exercises such as squats, presses and slow pulls. After the strength portion of the speed-strength equation has been appropriately developed, then the conversion to speed-strength may take place. Initially exercises such as jump squats, bench press throws and the simpler variations of the olympic lifts (power shrugs, hang clean above the knee, snatch pull from knee to chest high, push press/jerks) should take precedence in training prescription. The more difficult olympic lifts (power snatch, power clean) may play an increasingly important role as the athlete develops. The greatest power output measured during one repetition, or portion of (Eg. over 150 ms), can be developed during the top pull or jerk thrust of the olympic lifts. The performance of these more complex lifts with large external resistances may present the final area for the exploitation of power development.

The choice of loads.

The choice of the appropriate loads for speed-strength development depends upon the exercise chosen and the objective of training. Table 4 depicts the power output from the core exercises with different relative percentages of 1RM performed by elite lifters in competition. The very highest intensities (100% 1 RM) in all cases have a lower power output as compared to submaximal loads, irrespective of the exercise. Again this would tend to illustrate the invalidity of the methodology of using the maximal load method (>90% or 1-3 reps) for developing speed-strength. As the load intensity decreases, the power output increases. Therefore even though the mass decreases and the distance the weight is lifted remains the same, the power output is substantially increased via a marked reduction in the time for lifting (i.e. increased speed of lifting).

However the increase in power for submaximal loads in the squat and bench press is far more marked than for the olympic lifts. For example, the figures in Table 4 illustrate the decrease to 92-93% of 1 RM in the squat results in a 39.8 % increase in power output but only a 13.6 % increase for the clean. This is due to the fact that the time for execution of the olympic lifts does not alter as drastically (Hakkinen et al.,1984) as must the execution time for squats and bench presses. Thus the olympic lifts can only performed quickly whereas traditional strength training exercises such as squats and bench presses could be executed at a variety of speeds, depending upon the magnitude of the resistance to be overcome.

This fact, that differentiated loads, have differing effects on power output in different exercises could also explain the debate between the relative effectiveness of heavy weights versus light weights in developing speed-strength. A loading of 80-90% 1 RM during the snatch may be extremely effective in developing speed-strength whereas for the bench press this loading may be excessively high resulting in a reduced power output. Whilst 50%-60% of 1 RM may be deemed an effective speed-strength load for the bench press (Santa Maria et al., 1985), it would appear that 30-40% of maximum may be more appropriate for the jump squat exercise (Wilson et al., 1993). However the total system mass (body mass plus barbell mass) should be taken into account in determining the appropriate load for a jump squat. For example, if an athlete weighs 80 kg and can full squat 160 kg then the system mass is 240 kg. Consequently 40% of the system mass equals 96 kg. Therefore the extra load may be only 16 kg to give the total load of 96 kg. Further evidence of this common discrepancy in choosing the extra jumping load (i.e. choosing 30-40% of 1 RM instead of 30-40% of the body mass plus 1 RM mass) is seen in the results of Poprawski (1987). The data presented for jump squats performed by elite shotputters with extra loads of 20kg through to 140 kg illustrates that the 20kg extra load produced the highest power output. As the average full squat was 185.5 kg, then this may be seen to represent only 10.8% of 1 RM. However if the total system load was 293.6 kg (185.5kg plus 108.1 kg body mass) then 20 kg plus body mass represents a figure of 128.1 kg or 43.6 % of the system mass. The extra jumping load of 60 kg representing approximately 30 % of the 1 RM full squat gave a much lower power output in comparison as the total system mass was actually 168.1 kg or 57 % of the maximum system mass. Research (Wilson et al., 1993) and training studies (Baker, 1994; Baker & Foley, 1994) have always taken the total system mass into account when determining the extra load for jump squats. If the total system mass is not taken into account or if the 1 RM strength results are based on half squats or parallel squats, then inappropriately heavy loads may be selected for the jump squats. Conversely many software packages are available that allow the strength coach to accurately determine the optimum load for jump squats.

Based upon the data analyzing power production or force and angular velocity during differentiated loading during strength exercises the following recommendations can be made:

1) the maximal loads in every exercise do not correlate with the maximal power output.

2) the highest power outputs or force/angular velocities occur with loads representing 80-90% 1 RM (2-5 repetitions) during the olympic style lifts. However during certain portions of the lifts, such as the top pull, then the figures could be 70-80% 1 RM.

3) sub-maximal loads of 60% or even less produce the highest power output in traditional strength training exercises such as the squat and bench press. However the use of this loading is severely compromised by the fact that a substantial deceleration period (greater than half of the lifting epoch) will

occur with these loads (Wilson et al. 1989). Training the musculature to decelerate over such as large distance could be extremely disadvantageous if the ultimate goal is to increase the ability to accelerate the limbs through a large range of motion.

4) the loads for jump squats can be determined as the load that produces the optimal power output. This is calculated by software such as the Plypower or Record Time. From the authors experience training elite divers, sprinters and rugby union players the load is usually in the range of 20-50 kg. Conversely 30%-40% of the1 RM squat plus body mass has been proposed (Wilson et al., 1993), although it may take a few weeks to safely introduce even this magnitude of loading.

Practical applications: Contrasting exercises and loads

The use of exercises/sets with training loads that are markedly different within a training session has been used extensively to increase speed-strength development (Fleck & Kontor, 1986; Spassov, 1989; Baker, 1993; Baker & Foley, 1994, Kemp, 1994). This method is based upon the premise that a heavy load has a neural stimulation effect. Subsequent lighter training loads then subjectively feel "lighter" after the completion of heavier loads. Theoretically the result is more powerful execution of the lighter training loads. For example, Baker (1994) reported that the best jump squat height during a second set could be improved by as much as 17% over that of the first set if a heavy set of six repetitions in the full squat is performed between the jump squat sets.

Whilst the exact neural mechanism has yet to be determined it is possibly due to a number of mechanisms such as increased descending activity from the higher motor centres, direct myoelectrical potentiation, increased synchronization of motor unit firing, reduced peripheral inhibition from the Golgi tendon organ, reduced central inhibition from the Renshaw cell and enhanced reciprocal inhibition of the antagonist musculature.

The patterning of the loads/exercises within a session has been used to distinguish between two popular methods that can be described as the Russian and Bulgarian speed-strength methods (Fleck & Kontor, 1986; Spassov, 1989; Kemp, 1994; Baker, 1994a). The Russian method involves the continual alternating of heavy loads and lighter loads (i.e. strength loads and speed loads). In this method the continually contrasting nature of the alternating loads provides stimulus for speed-strength adaptations. The Bulgarian method involves working from the heaviest loads progressively down to the lightest loads. Thus the loads are getting progressively lighter and hence the muscles should be able to contract slightly faster with each reduced load. Table 5 depicts how these two methods have been modified and implemented in improving the speed-strength of elite divers from the Australian Institute of Sport. The speed-strength training of the AIS divers always contains some variation of either of these two methods.

The contrasting methods of speed-strength would appear to offer an efficient method of speed-strength development by simultaneously training both maximal strength and speed-strength. Recent research has found that this method of contrasting loads as equally effective as optimal power loads in improving various speed-strength parameters (Lyttle & Wilson, 1994). The practical experience of the author who has been implementing these methods since 1986 would suggest that the light load/exercise be done for full acceleration for the full range of movement. Examples would be heavy squats and jump squats, heavy bench press and bench press throws (in a smith machine) or medicine ball pass, heavy clean pulls and light clean pulls, heavy cleans and light cleans. In each of the listed pairs of exercises above, the second exercise is an exercise that allows for full acceleration over the entire range of movement. If the light exercise load is performed as a standard squat or bench press for example, then the large deceleration period identified with such loads of 50-60% (Wilson et al., 1989) interferes with the objective of developing acceleration/power.

The contrasting load/exercise method would appear to be a promising avenue for developing speed-strength. Further research and practical implementation is warranted.

Individual differences

The individual characteristics of the sport or the athlete may indicate that even some power exercises may be more appropriate than others in developing sport specific speed-strength. For example, elite divers have a time frame of 350-500 ms for the application of force against the springboard or tower (concentric contraction time) (Miller et al., 1989) and only body mass as a resistance to overcome. A rugby league prop has a more varied time periods for application of force and the external resistances to be overcome are much larger (Eg. attempting to burst through three opposition tacklers). Consequently although both athletes require speed-strength, the factorial requirements of the equation differ markedly for both athletes. For the diver, a greater emphasis is placed upon light jump squats and various weighted plyometric jumping exercises with only a minimal amount of maximal strength training (Baker, 1994; Baker & Foley, 1994). Therefore the speed-strength training of a diver is characterized as high power output achieved against low external resistances. For the rugby league prop, the power output must also be very high but characterized as achieved against large resistances that will condition him to the large external resistances he must overcome in his position/sport. Therefore exercises such as split and power jerks, power clean from the hang, pulls etc. tend to dominate the training dosages of a rugby league prop. Maximal strength exercises such as squats and bench presses also warrant a greater training dosage. If jump squats were to be performed, the loading may also be considerably higher if this can be safely achieved (Eg. body mass or greater on the Plyopower machine, using the brake to reduce impact forces).

More recently some evidence or theories exists that as an athlete becomes stronger the absolute or relative loading that are the most effective in developing power may change. Poprawski (1987) suggested that stronger, slower athletes needed to train with higher relative % of 1 RM (circa 70%) in comparison to "weaker", though faster athletes (circa 50%). These loads may be more suited to the olympic style lifts that he recommended for speed-strength development more so than the bench press for example. Bemben et al. (1991) reported that as athletes became stronger in the bench press exercise the power output at any relative load (% 1 RM) decreased because the extra load took longer to lift. In a follow up investigation Mayhew et al. (1992) reported that power output at any given absolute load (Eg. 50 kg) increased as the athlete became stronger because presumably this absolute load becomes relatively lighter and consequently could be lifted with more speed. Thus the load that produced the peak power output in this second study increased from 40% of the original 1 RM to 50% of the original 1 RM because the subjects increased their strength by almost 10%. As athletes become stronger the advantage appears to lie in the fact that they can produce greater power outputs with any absolute loads but the ability to produce power at any given % of the current 1 RM is compromised by the fact that relative resistances keep increasing along with the maximum strength levels. This may explain why researchers such as Hakkinen & Komi (1985a; 1985b) have utilized absolute loads such as 20 kg, 40 kg, 60 kg etc. when testing speed-strength adaptations.

Therefore the individual differences such as the sport specific time of the application of force, external resistances to be overcome in the sport and the individual requirements of the athlete need also to be considered.

Changing strength levels may also warrant consideration as to which loads/exercises are most appropriate for developing speed-strength.

Conclusions

A rationale has been provided for the definition of speed-strength as power. Some current recommendations concerning training to improve this muscular quality proposes the use of high loads, based upon the isometric testing of the musculature. It would appear invalid to extrapolate the results of isometric research using unilateral isolated exercises to multijoint, dynamic strength training exercises. Speed-strength implies both speed and strength, whereas the high load method of training emphasizes strength far more so than speed. Both components of the equation should be considered and the power output possible during an exercise may be used to discriminate whether an exercise is appropriate for speed-strength development.

Exercises that have been shown to produce the highest power output have been the lifts taken from the sport of olympic style weightlifting as well as exercises where full acceleration takes place across the full range of movement such as jump squats or push press throws.

Submaximal loads always bring about the highest power output irrespective of the exercise. For the olympic style lifts the range of optimal power output is usually 80-90% of 1 RM, however during various phases of the lifts 70-80% may also be productive. For the traditional strength exercises such as squats and bench presses loads of around 40-60% may appear the most productive. These loads, however, are associated with a large epoch of deceleration that may make them counterproductive to the objectives. For jump squats 30%-40% of the total 1 RM squat plus body mass system may be a load that is close to the load that brings about the maximal power output.

Contrasting exercises and loads have been used to develop power in athletes. The two main methods may be classified as the Russian or

Bulgarian speed-strength methods. Both methods are based upon the premise that light loads may be lifted faster after lifting heavier loads to stimulate the neuromuscular system.

Individual and sport differences may further indicate what degree of manipulation of training variables occurs to achieve the objective of improving speed-strength to increase sport performance.

Table 1. The absolute and relative power output of selected elite lifters during competitive weightlifting and powerlifting exercises.

Subjects	**Exercise**	**Watts**	**Watts/kg**
	Powerlifting		
Lightweight male	Bench press	267	4
Heavyweight male	Bench press	415	4
Heavyweight male	Full squat	900	12
Heavyweight male	Deadlift	" "	12
	Weightlifting (male)		
Lightweight male	Snatch	2675	34.3
Heavyweight male	Snatch	2920	29.8
Lightweight male	Clean	1677	30.1
Heavyweight male	Clean	2772	28.3
Heavyweight male	Jerk	3881	31.0
Elite male	2nd pull of clean/ snatch or jerk thrust	6981	52.6
	Weightlifting (female)		
Female lightweight	Snatch	1423	23.8
Female lightweight	Clean	1281	21.4
Female heavyweight	Snatch	1932	23.6
Female heavyweight	Clean	1852	22.6
Elite female	2nd pull of clean/ snatch or jerk thrust	3691	39.2

* Data from Garhammer & McLaughlin,1980; Garhammer,1985;1989; 1991; 1993

Table 2. Estimated power output during a 100% 1 RM effort for different exercises for a theoretical athlete with a body mass of 75 kg.

Exercise	Mass x	Gravity x	Height	= Work /	Time	= Power
	(kg) x	9.81 x	m	= J /	s	= W
Bench press	100 x	9.81 x	.4	= 392 /	2	= 196
Deadlift	170 (75)* x	9.81 x	.5	= 1202 /	3	= 400
Full squat	140 (75) x	9.81 x	.65	= 1370/	2.75	= 499
Half squat	170 (75) x	9.81 x	.32	= 769/	2	= 385
Power clean	90 (75) x	9.81 x	.85	= 1375/	.8	= 1719
Squat clean	100 (75) x	9.81 x	.7	= 1202/	.7	=1716
Clean pull (to waist)	100 (75) x	9.81 x	.6	= 1030/	.6	= 1716
Split jerk	100 (75) x	9.81 x	.25	= 429/	.25	=1716
Top pull (knee to chest)	90 (75) x	9.81 x	.4	= 647/	.35	= 1849

* All lifts except the bench press also require the lifting of the body mass (75 kg). The barbell mass and the body mass become the system mass and this combined mass is used to calculate power output. Only the concentric portion of the exercise is used for analysis.

Table 3. Power output during a single loaded jump squat and multiple loaded jump squats for different athletes.

Subjects	Power	Power/kg
Single loaded jump squat		
Elite shotputters*	3559	32.9
Explosive strength trained males **	2086	27.0
Heavy strength trained males **	1910	24
Elite developing rugby line-out jumpers (n= 9)	1869	16.3
Multiple repetition loaded jump squats (3 reps)		
Elite developing rugby line-out jumpers (n = 11)	3936	39.7
Best individual effort from above group	4516	50.2
Elite male springboard diver (international gold medalist)	4726	63.9

* Data from Poprawski (1987). ** Data from Hakkinen & Komi, 1985a; 1985b. Rugby and diving data collected by the author, with the power output estimated by the Record Time software. The load of the barbell upon the shoulders was 20-50kg for all subjects listed above.

Table 4. Power outputs at different relative percentages of 1 RM for various strength exercises performed by elite strength athletes.

Exercise	% 1 RM	Power (w)	Barbell mass (kg)
Squat	100 %	900 w	420 kg
Squat	93 %	1259 w	390 kg
Snatch	100 %	2173 w	142.5 kg
Snatch	98 %	2298 w	140 kg
Snatch	100 %	2675 w	-
Snatch	95 %	2821 w	-
Clean	100 %	2772 w	217.5 kg
Clean	96.5 %	2897	210 kg
Clean	100 %	3413	-
Clean	92 %	3877	
Bench press	100% of 2 RM	247	-
Bench press	85 % of 2 RM	366	-
Bench press	60 % of 2 RM	481	-

* Data from Garhammer & McLaughlin, 1980; Garhammer,1985;1989; Santa Maria et al., 1985.

Table 5. Examples of the Bulgarian and Russian speed-strength methods may be modified and implemented.

Bulgarian speed-strength method (kg/reps)			
Squats	95/6	95/6	95/6 -->
Jump squats	40/4	40/4	40/4 -->
Loaded jumps*	4.5/4	4.5/4	4.5/4 -->
Russian speed-strength method			
Squats --> Jump squats	95/6 --> 50/4 -->		
	105/6 -->50/4 -->		
	110/6 --> 50/4 -->		
Clean pulls --> power cleans	120/3 --> 60/3-->		
	130/2 --> 70/3 -->		
	130/2 --> 70/3-->		

* Loaded jumps signifies vertical jumps with a small load attached to the waist (Eg. 4.5 kg). Data modified from Baker & Foley, 1994 (except example of clean pulls and power cleans).

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