STRENGTH TRAINING OF THROWERS

By Dr. Klaus Bartonietz

Leading German sport scientist, Dr. Bartonietz, discusses strength development methods and takes a close look at some common resistance exercises used by throwing exponents. The article is based on translated and slightly abbreviated extracts from the author's lengthy contribution titled "Modern Understandings of the Development of Maximal Strength Capacities" that appeared in Die Lehre der Leichtathletik, Vol. 43, No. 14-16, 1995. Re-printed with permission from Modern Athlete and Coach.

INTRODUCTION

The rapid improvements of international performances in throwing events over the last 20 to 30 years have been closely related to the improved training methods in the development of specific strength. In strength training we are faced with the following different areas:

General Strength Training

Nature: The movement structure of the exercises has only very limited relation to the actual competition exercise.

Aim: To develop muscle groups that have assisting functions, improvement of the load tolerance of the tendons and support tissues, and the elimination of muscular imbalances.

Example: Exercises similar to those employed in maximal strength training with loads not exceeding 50% of the actual best lift, exercises using strength training machines, partner exercises.

Maximal Strength Training

Nature: The movement structure has limited relation to the competition exercise but includes the main involved muscle groups.

Aim: Improvement and stabilization of the work capacity of the main muscle groups to establish a base for specific strength training.

Example: Classic barbell exercises, performed mainly in the 75 to 90% intensity range, exercises on strength training machines with high loads.

Specific Strength Training

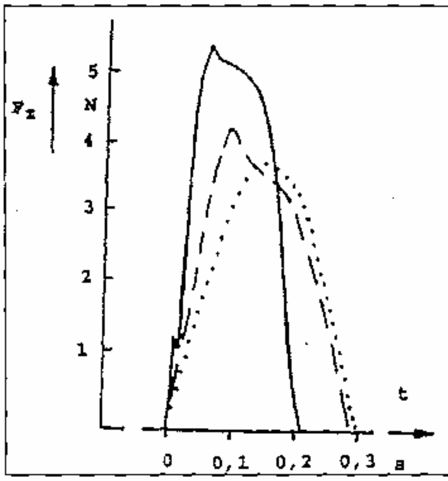
Nature: Increased demand on single performance decisive parameters of the competition exercise.

Aim: Improvement of the work capacity under event specific conditions, using a load structure that is similar to the single elements of the competition exercise and performing competition exercises with additional loads (heavier implements, throws wearing a weight jacket).

DIRECTION OF THE TRAINING EFFECT OF SELECTED EXERCISES

There is a familiar saying that “each throw is built up from the legs”. We will therefore in the following look at the directions of the training effect in selected exercises on the development of specific strength capacities with particular attention paid to lower extremities. The biomechanical components of the training effect of the chosen exercises are determined by the movement structure and the characteristics of the external resistances. In addition, the actually achieved adaptations are also influenced by the temporal arrangements and sequences of the training exercises and complexes of training means.

It should be noted that the different tests and training exercises (for example, squats, snatches, jumps, isometric exercises) have more than twice the performance value when executed on a single leg. This “bilateral” difference between single and double legged exercises is apparently created by the neural mechanisms. From a biomechanical viewpoint, single leg exercises allow to ascertain higher loads on single extremities in the execution of the exercises. (Fig. 1 and 2).



PERFORMANCE	DOUBLE LEGGED	SINGLE LEG	
		RIGHT	LEFT
CONTACT TIME (S)	0.20	0.30	0.29
HEIGHT OF JUMP (M)	0.49	0.22	0.18
FORCE VALUE AT TAKEOFF EXTENSION (G)	5.0	3.6	3.3
DEPTH JUMP INDEX	3.45	1.40	1.31

FIG. 1: Ground reaction force-time graph in single and double legged jumps (discus throwers)

The load changes from the driving to the braking leg are relevant in the performance of throwing events and therefore significant in the execution of training exercises. Hypothetically, an unsatisfactory specific strength development can occur when single leg test performances reach only half of the double-legged test values. (Fig. 1). Kiebele, et. al. asked already in 1991 whether bilateral strength training could be inefficient in the training of throwers. As experimental studies in this field are unknown, it appears that single leg exercises should after an appropriate preparation be systematically employed in the strength training of throwers to improve the specificity of the training load.

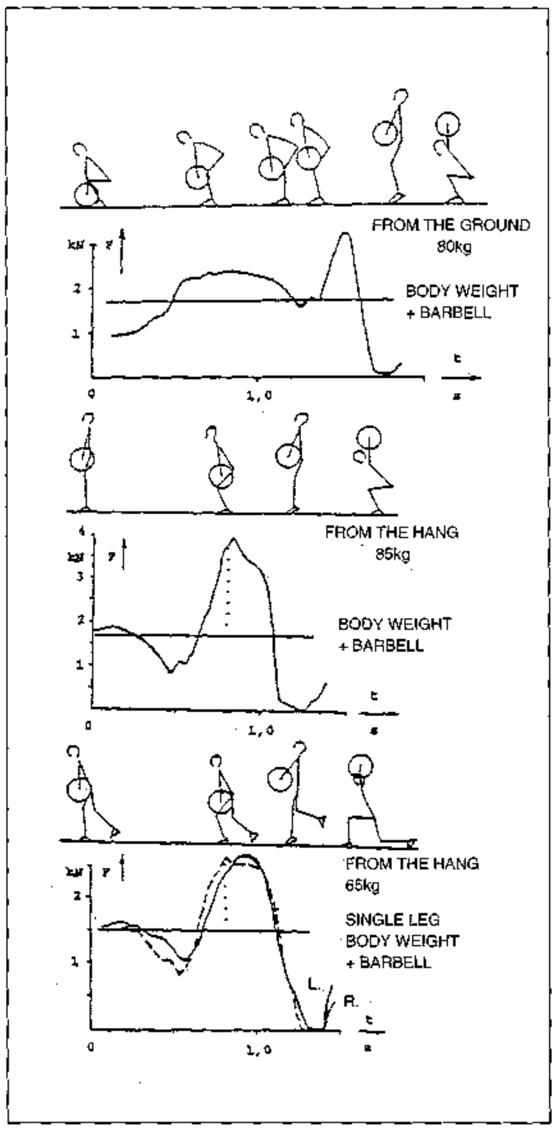
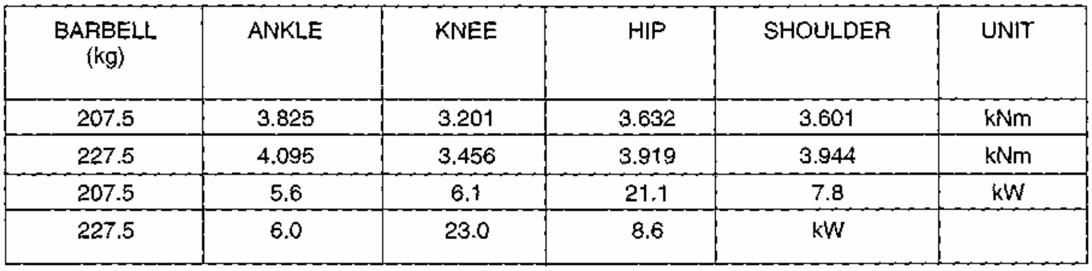


FIG. 2: Ground reaction force-time graphs in the snatch (Bartonietz/Gullich 1993)

THE SNATCH

The classic snatch, the competition exercise for weight lifters and basic lifting exercise in the training of throwers, is characterized by two pulling phases which are recognizable from the barbell velocity and the ground reaction forces. (Fig. 2, top). As far as the resulting muscle force momentums are concerned, the demands on the ankle, shoulder, hip and knee forces (Table 1) are in comparison virtually similar. However, the demand on hip extensors dominate the joint performances and play a leading part in the execution of the training exercises (Wide 1986). It can be hypothetically accepted that the data given in Table 1 is applicable to all performance levels.



BARBELL (kg)	ANKLE	KNEE	HIP	SHOULDER	UNIT
207.5	3.825	3.201	3.632	3.601	kNm
227.5	4.095	3.456	3.919	3.944	kNm
207.5	5.6	6.1	21.1	7.8	kW
227.5	6.0	23.0	8.6	kW	

TABLE 1: Influence of the barbell mass on the maximal values of the joint moments (kNm) and the joint performances (kW). (From results by Weide 1987)

The work of plantar flexors in the ankle joint is frequently underestimated in the performance of the snatch. It has two significant aspects in:

- Contributing up to 10% to the barbell velocity
- A performance-deciding element in the ankle drive in throwing events.

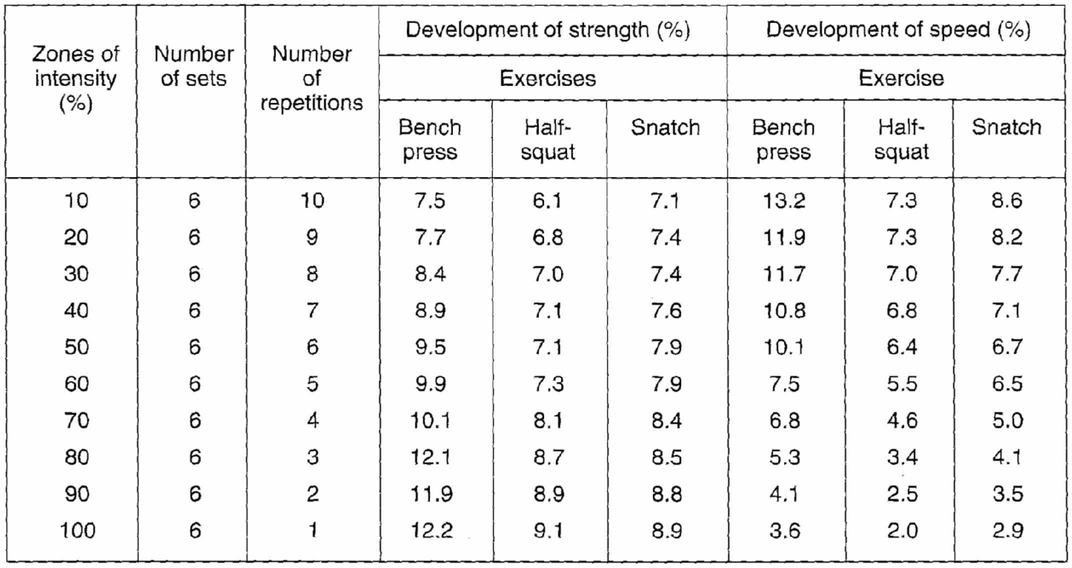
It is therefore advisable to set high loads to the plantar flexors of the ankle joint even when it is limited by the external resistance. An explosive force application in the snatch is made possible from the hip (from hanging) or from an elevated barbell position, as the knee and hip extensions reach their relative maximal velocity level at the same time. The ground reaction force-time graph (Fig. 2) also reveals a distinct force acceleration phase. This indicates that joint moments and joint performance apparently reach higher values in the exercise than in the execution of the classic snatch.

The lifting work produces in maximal strength exercises multiple accelerations, as can be seen in a sample calculations (barbell 100kg, maximal velocity 2m/s, lifting path 1.2m):

- Lifting work: $m \times g \times h = 100 \times 9.81 \times 1.2\ (kgm^2/s^2) = 1200$ Ws
- Acceleration work: $m/2 \times v^2 = 50 \times 4\ (kgm^2/s^2) = 200$ Ws

The dominating lifting work begins already from medium loads and reaches in the close to the maximal load range 10 times the contribution made by acceleration work (Bartonietz 1987). From this follows the recommendation by Bosco (1992) to consider the acceleration performance in the development of maximal strength capacities. On the other hand, weightlifters have for years successfully guided their training by the lifting performance. They believe that the training effect of an exercise depends, besides the load, also on movement speed and control their training according to the so called speed-strength performance (PSK). This value is calculated from the external mechanical performance at the time of the maximal barbell speed.

For example, the intensities in training range from intensity 1 (90-100%) over intensity 2 (75-89%) to intensity 3 (<75%). A thrower has a best snatch performance of 100kg, reaching a velocity of 2.0m/s (PSK 2kW). This athlete should consider using intensity 2 in training because he can possibly even reach a maximum speed of 2.35m/s to perform 2 kW mechanical work. Such calculations are significant because the sample 85kg snatch at 2.15m/s reaches already the intensity zone 1 (1.83kW). As can be seen, training control that is based only on the barbell load can lead to significant shortcomings when movement speed is overlooked. Consequently it is advisable to adjust load increases for young throwers according to movement speed and the quality of the exercise execution.



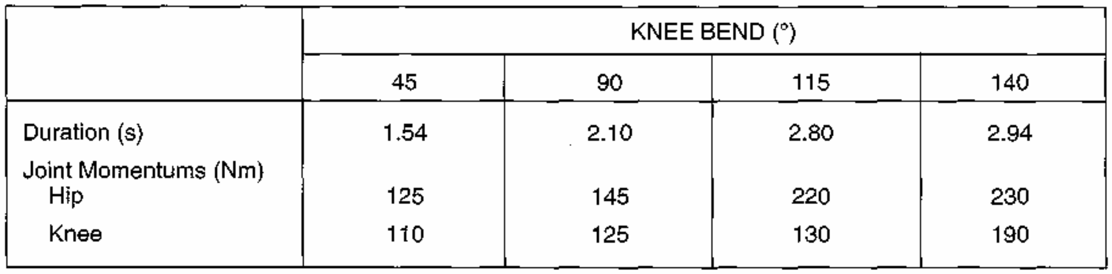
Zones of intensity (%)	Number of sets	Number of repetitions	Development of strength (%)			Development of speed (%)		
			Exercises			Exercise		
			Bench press	Half-squat	Snatch	Bench press	Half-squat	Snatch
10	6	10	7.5	6.1	7.1	13.2	7.3	8.6
20	6	9	7.7	6.8	7.4	11.9	7.3	8.2
30	6	8	8.4	7.0	7.4	11.7	7.0	7.7
40	6	7	8.9	7.1	7.6	10.8	6.8	7.1
50	6	6	9.5	7.1	7.9	10.1	6.4	6.7
60	6	5	9.9	7.3	7.9	7.5	5.5	6.5
70	6	4	10.1	8.1	8.4	6.8	4.6	5.0
80	6	3	12.1	8.7	8.5	5.3	3.4	4.1
90	6	2	11.9	8.9	8.8	4.1	2.5	3.5
100	6	1	12.2	9.1	8.9	3.6	2.0	2.9

TABLE 2: Development of speed and strength in different intensity zones in the process of strength training for throwers. (Bondarchuck 1994)

This approach was first introduced by LenzlFrolich in 1990. It was based on the studies by Hofmann/Kullmann, who recommended speed orientated weight training with a reduced total load. The latest experiments by Bondarchuk have confirmed that movement speed orientated weight training exercises allow to develop strength capacities (Table 2). The results of the strength training studies by Buhrle (1993) give further support to the so called speed-strength method (maximal speed execution with a relatively limited external resistance) because throwers are looking for a force application with a final acceleration, not for a maximal initial acceleration.

THE SQUAT

Squats with high loads develop mainly hip and knee extensors. The key in the movement execution is the braking procedure at the lowest turning point. The influence of this phase on the size of the joint momentums is presented in Table 3.



	KNEE BEND (°)			
	45	90	115	140
Duration (s)	1.54	2.10	2.80	2.94
Joint Momentums (Nm)				
Hip	125	145	220	230
Knee	110	125	130	190

TABLE 3: Maximal joint momentums in different knee angles in the executions of squats (median values).

The electromyographic studies by Wretenberg et. al. (1993) make the following conclusions possible:

- The upward hip extension momentum is dominant (also in the squats performed against the clock)
- The maximum momentums are reached at the turning point of the squat. (This also applies to maximal ground reaction forces).
- The hip momentum increases with the knee angle in which there are significant quality differences observed between the 90° and the 115° (thighs parallel to the ground) angles.
- There are quality differences between the parallel knee angles and deep knee bends in the knee extension momentum.
- The parallel and deep knee bends produce a significantly higher muscular activity in comparison to reduced knee angles.
- Parallel knee bends develop joint momentums that differ only slightly from those occurring in deep knee bends. They are therefore preferable in order to prevent knee problems.

The performance of the squat, besides the load, knee angle and velocity, requires a strict control of the execution of movements, because the training effect depends largely on the movement quality. It should be noted here that a 10° variation in the knee angle can lead to 25% differences in the joint momentums (Hilderbrand/Krause, 1990). This indicates that the same load allows in different knee angles a wide variation of training effects. A higher load on the knee extensors can be reached by reducing the extension movement of the upper body, which is achieved in the performance of “front squats”. It reduces the load on hip extensors and with it relieves the load on the spine.

The load and velocity relationship discussed in the performance of the snatch is also applicable to the squat. Test values of Werner Gunthor (Fig. 3) show that a maximal “speed-strength performance” can be achieved in a relatively large load range between 160 to 220kg. The power output was maximal even with the 160kg load. In contrast, loads in the 120 to 140kg range were not lifted faster, apparently to avoid jumping. (Theoretically it should be possible to reach a speed of 1.45m/s but the actual velocity was only 1.22m/s).

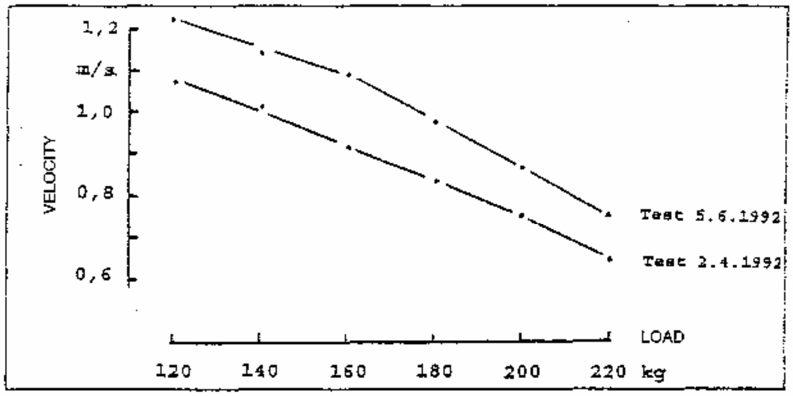


FIG. 3: Development of Werner Gunthor's squat performance (Egger et. al. 1992)

REACTIVE JUMPS

Reactive strength capacities of lower extremities play an important part in several phases of throwing events. The development of these capacities can be explained by using depth jumps as an example. At the same time it should be noted that horizontal jumps are more specific to throwing events and should therefore in methodical sequences take place after vertical jumps.

Reactive jumps place high demands on the plantar flexors of the ankle joint during the short contact time in the changes to vertical or horizontal direction. The main training effect in reactive vertical changes occur in the knee extensors. It should be noted that even depth jumps from lesser heights set high demands on plantar flexors because of a limited rotational momentum of the hip muscles. Several studies have suggested optimal dropping heights, which naturally depend, besides the individual performance level, also on the specific requirements of a particular event. Unfortunately the available information on ranges is extremely wide and fails to provide precise recommendations. For example, Hakkinen et. al. presented in a study of weightlifters a range from 0.2 to 1.0, while an experiment by Schmidtbleicher suggested heights between 0.32 to 0.56m.

The event specific demands in throwing appear to suggest relatively low depth jumps to develop reactive strength capacities (double-legged jumps from a height of 0.2 to 0.3m without the heels striking the ground). There are relatively large differences between single or double-legged depth jumps (Fig. 1), because throwing specific development can be expected only when one leg is loaded by more than one half of the athlete’s own body weight. Further, the height of single leg depth jumps should exceed by more than one half that of the double-legged jumps.

It is therefore advisable to evaluate reactive strength capacities in depth jumps by using a force platform to determine the individual index from the following:

- Index = height of the drop + rebound height/contact time (Dickwach et. al. 1991).

This depth jump index takes into consideration falling speed, takeoff speed and the duration of the direction change. Using only the rebound height to select the optimal drop height fails to consider the changes in the takeoff phase. The results of an experiment by Schmidtbleicher indicated that ground contact times from heights between 0.32 and 0.56m can remain relatively constant (0.21 to 0.25s). These contact times are not applicable to throwers, whose surface contact among elite performers is clearly shorter. For example, elite hammer throwers — drop height 0.3m, ground contact 0.13 to 0.16s (Bartonietz/Gaede 1994).

Out studies revealed a distinct correlation between the surface contact time and the maximal force. Further studies showed that increasing the drop height by 3.5cm (with only a limited reduction of the contact time by 0.01s) was responsible for a considerable increase in EMG activity in the involved muscle groups. The reflex phase immediately after the ground contact produced higher EMG activity in jumps from limited heights (0.32 and 0.40m) than in jumps from 0.48 and 0.56m. This stresses the specificity of the adaptation processes. Loads that are too high (drop height or additional loads) lead through longer contact times to an unwanted innervation reduction.

It becomes obvious from the above outlined experiments that the stretching - shortening cycle of the muscular contraction in depth jumping does not automatically correspond to the leg work in the competition exercises. We should therefore strive to find specificity in strength development also in the use of reactive jumps.