# BIOMECHANICAL ASPECTS OF THE PERFORMANCE STRUCTURE IN THROWING EVENTS

**By Dr. Klaus Bartonietz**

*Leading German biomechanist, Dr. Bartonietz, who recently lectured in Australia, presents his views on the theoretical and practical aspects of the biomechanical performance structure in throwing events, stressing the close relationship between technique and mechanical performance capacity. The following article is a slightly abbreviated translation from Die Lehre der Leichtathletik, Vol. 34, No. 14, Apr11 1995 on which Dr. Bartonietz's Australian lectures were based. Re-printed with permission from Modern Athlete and Coach.*

Knowledge of the demands of an event is necessary for planning and implementing training, since the structure of the competition performance determines the training structure. The release velocity of the given mass of an implement represents the energy the competition implement receives from the thrower. This velocity corresponds to the acceleration force impulse (integral of the acceleration force over time). The created forces are therefore the result of the conversion of the driving system and limited by it.

The acceleration performance Pa in the competition exercise expresses the amount of energy transferred to the implement in the available event specific time:

$$Pa = \frac{\Delta K_{kin}}{\Delta t} \; ; \; Pa = Fa \times v$$

The acceleration performance has a constant relationship with the event specific work conditions (mass of the implement, initial velocity, useful braking and acceleration paths). These parameters are, next to the energetic aspects, an inseparable aspect of a sporting technique (Fig. 1-3).

Fig. 1 (top left) illustrates the required increase in the javelin acceleration according to model calculations (initial speed at t = 0/s, 6m/s, acceleration path = 1.5m). The characteristic changes of the fore-time graph that result from delays in the acceleration are also shown in actual measured throws (comparison between individuals and differences over several years). Fig. 2 indicates clearly that higher acceleration values must be created when the rotational technique is used in the shot put because of a lower implement speed at the placement of the propping leg and a shorter acceleration path. The acceleration performance therefore offers a means of evaluating the effectiveness of techniques (Bartonietz 1990, 1994).

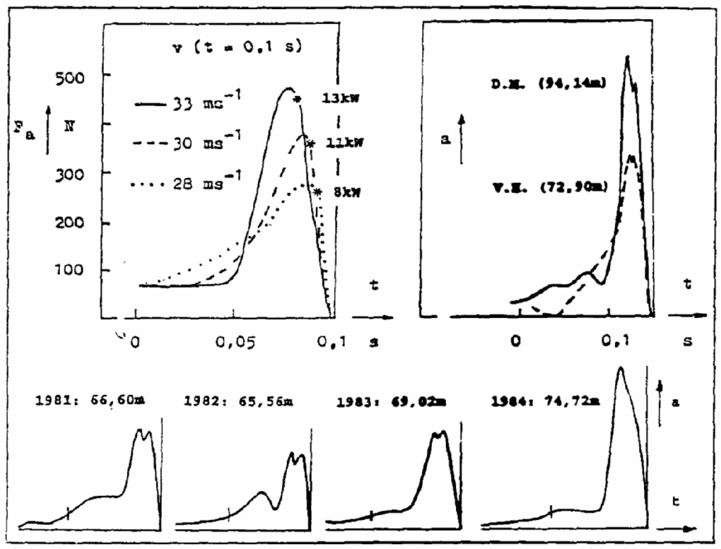


*FIG. 1: Changes in the final acceleration impulse* ***in the javelin throw*** *with an improved performance capac ity and the required maximum acceleration.* ***Above left: model calculations*** *(Schwuchow 1986); above righ real values measured with a tenso javelin* ***(Bartonietz 1987); below:*** *measured values of a female athlet over several years (vertical line indicates the* ***propping leg placement****).*

In the end, it is the implement that needs a maximal acceleration that is not necessarily achieved from a greater skeletal-motor drive (see the pivoting leg comparison in Table 1). An efficient and correct development of strength capacities for a target technique in unity with the actual technique level is therefore unavoidable. An “over potential” of strength capacities only means additional training time and more mechanical loading of the movement apparatus.

Assessments of the mechanical performance capacity of the leg drive can be made indirectly in the execution of the competition exercise. If it can be assumed that the initial velocity for the final acceleration phase has not significantly changed over the years (or at least not diminished), then such characteristics as the body positions, time intervals and ground reaction force-time graphs provide qualitative information on this acceleration performance. An example of two hammer throws (Fig. 3) by an elite athlete illustrates how a larger amount of energy is transferred in a shorter time and clearly higher physical performance is created.

We will realize the difficulties which are ahead of an athlete and his coach when a young hammer thrower with a 5kg implement turns slower than Sedych in his 86m throw and has a release velocity that is about 5 m/s slower. With increasing hammer masses (from 5kg to 7.26kg) the athlete needs large amounts of energy to be transferred to I implement in shorter time intervals. Consequently, the throwing technique must be developed towards a longer acceleration path (wider radius).

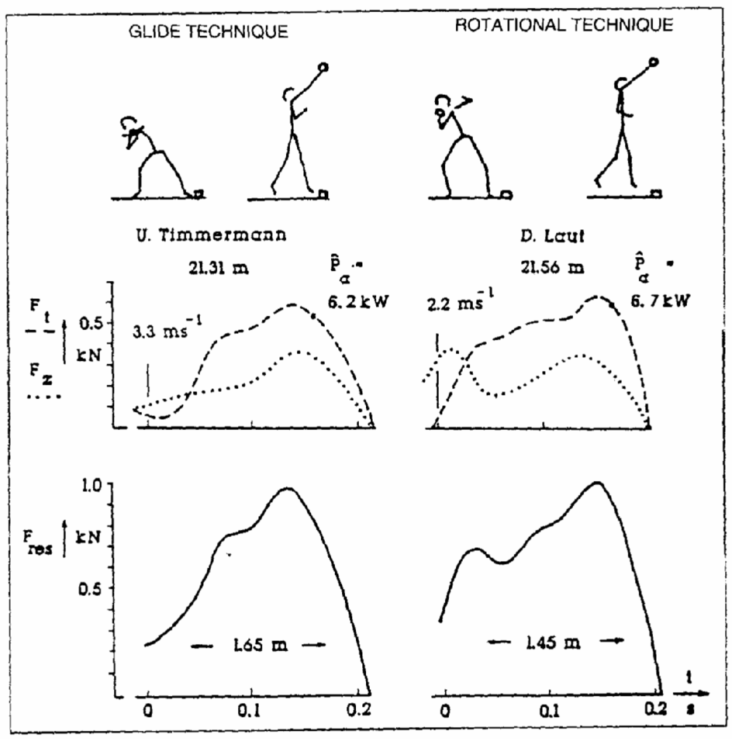


*FIG. 2: Final acceleration impulse and the maximum acceleration performance in the shot put (Bartonietz 1990) $F_t$ = tangential component: $F_{res}$ = total force; $F_z$ = centripetal component.*

Consequently it is again clear that here "no strength increase in itself". There is inseparable relationship between sporting technique and the mechanical performance capacity: no technique is possible without performance and no performance is possible without technique. Consequently, perfection of technique has to be seen as a full year task, even when the development of technique is not in the centre of the program.

An improvement of the performance with the competition implement therefore requires:

1. A forced prerequisite of a larger contribution of mechanical work (improved maximal strength capacity). This improved work capacity must allow for;

2. A higher performance production within event specific conditions that is originated from the legs, trunk and the throwing arm.

This leads to the question of how are the basic work capacity (maximal strength) and the impulse performance (specific capacity) to be developed and which neuro-muscular mechanisms are available for this task. The following possibilities are significant:

The development of a refined morphological structure of the neuro-muscular system, in particular increased functional muscular cross-section areas that can be evaluated from the muscle mass and fiber length. According to the present scientific opinion the number of muscle fibers are in humans determined genetically and do not undergo any changes through training.

Methodological application: Training programs of a maximum of 10 to 12 weeks with up to four training units a week with a medium intensity (60 to 80% of the actual best performance). The execution of weight training exercises at maximal speed produced only limited (Adekseyev/Roman 1976, Vorobev 1981) or no (Thorstenson 1975) cross-sectional increases in the trained muscle groups.

Event specific differences of the desired hypertrophy depend on the mass of the implement and the external forces. The shot put and the hammer throw are relatively hypertrophy orientated, while the lowest orientation occurs in the javelin throw. This is confirmed in the training analyses of Fuchs (1981) and Schuler (1986), indicating that a volume orientated strength training directed towards hypertrophy is inappropriate for elite javelin throwers. Muscular hypertrophy, in the context of event specific demands, is the task of maximal strength training over several years.

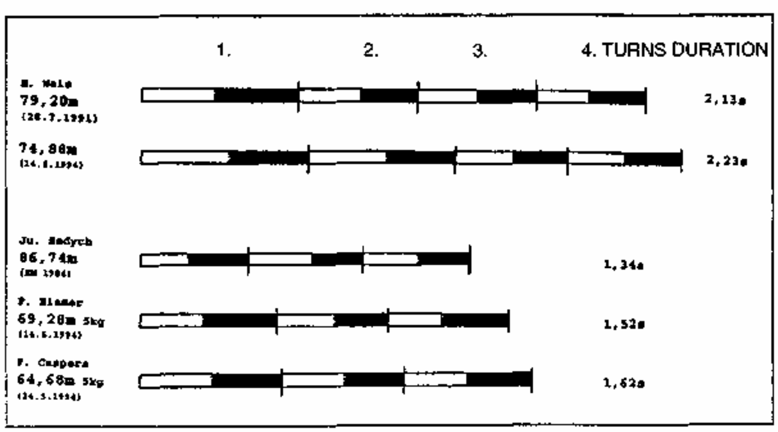


*FIG. 3: Duration of single and double legged support phases, as well as the total time of the turns for different level hammer throwers (☐ = single leg support; ■ = double legged support.)*

As a loss of optimal mechanical characteristics of the muscles (stretching capacity, elasticity) must be avoided, there are limits to the development of hypertrophy.

The improvement of neuro-muscular control, particularly the recruitment of a larger number of motor units (using the so called "autonomons protected reserves").

According to Hettinger (1972) and Asmussen (1981), only about 2/3 of all muscle fibers are simultaneously innervated in untrained persons. In order to make better use of the available potential, the degree of innervation must be raised. Estimation by Buhrle (1993) indicates that an additional recruitment could increase the contraction force of a motor unit, for example the gastrocnemius, by 0.5N. According to our calculations, only an acceleration force of 5N is needed to increase the release velocity in the men's shot put by 0.14 m/s, corresponding to 0.3m in distance.

Contraction force can also be varied through the changing of unloading frequency. However, it should not be overlooked that, from the throwing specific viewpoint, it is not a question of developing fast high levels of strength ("explosive strength") but to improve the final acceleration. That is, to accelerate from an already high speed level. An optimal timing is here also required.

Methodological application: single repetitions with maximal or super-maximal loads (attempts with loads that are above the current best) and the use of the highest level of willpower. The effectiveness of this has been proven in strength training experiments, e.g. I ai Fukunaga (1970), Schmidtbleicher (1982, 1984), Bravaja (1984), Kriegel (1986).

Further, it is necessary to improve the biochemical energy metabolism (energy provision, energy conversion and the control of energy conversion) and to adapt the tendon-ligament structure to the constantly increased loads. This load tolerance capacity becomes often a limiting factor in throwing events. The employment of volume orientated training with lower intensities is here useful (Zaciorskij et. al. 1981).

Energy conversion can in competition specific work be brought to a higher level by the improvement of intra- and inter-muscular coordination through the activation of a larger number of motor units involved in the performance (movement coordination for effective driving and braking leg work in the final force application optimization of the antagonist input). This allows making use of the performance improving potential of the stretching-shortening cycle of muscular work. The energy release can be further increased, and even doubled in the ankle joint, from the elastic qualities of the muscle-tendon complex (Huijing 1994).

The stretching-shortening cycle should in throwing events be regarded as working together with the different weight implements and movement speeds (standing throws, shorter or longer run-ups). It is a matter of specific adaptation to the relevant masses and movement speeds. For this reason, standing throws, or throws from a few strides, should be reduced to a minimum. It is relevant in the stretching-shortening cycle for the final acceleration to note that there is a difference in the movement coordination in whether the process of stretching the shoulder-chest area is initiated by a forced braking of resistance, or whether it is achieved from an active preliminary preparation of the upper body in a delayed throwing arm (shot, discus, javelin).

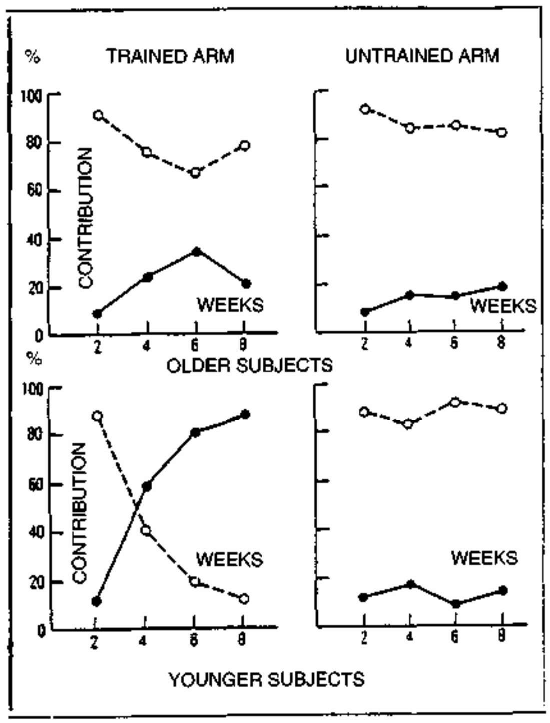


*FIG. 4: The temporal progress of strength increases in dependence of the contribution form neural factors (0---0) and muscle hypertrophy (●---●) according to Moritani/de Vries 1980*

Methodological application: development of a high load toleration and recovery potential, use of specific strength training exercises and heavier implements, use of lighter implements (in the high performance range relevant only to the javelin), development of the reactive strength capacity in the lower extremities.

Which of these mechanisms, or which combinations, can be best employed to improve performance depends, next to the event specific qualities, on individual demands and training targets (for example, long-term multi-year development with or without changes of implement weights, annual training structure, evaluation of technique reserves, preparation and capacities levels). This means in practice to control the adaptation processes so that the training loads are directed to achieve higher acceleration performances within event specific conditions through an increased work capacity (maximal strength training).

It has been proven that the development of maximal strength with gradually increased specificity is successful as the performance capacity improves (increased specificity of the training stimulus). It can be assumed that through this specificity in strength training we can avoid the danger of instability in the development of technique. This exists when extremely concentrated training stimuli are applied in maximal strength training phases.

Whether it is necessary in the desired specificity to go as far as suggested by Bondarchuck (1993) is worthy to be discussed further. Bondarchuck's training based studies of 60 throwers over several years came to the conclusion that using mainly general strength development exercises during the early stages of training is less effective than a long-term training method that contained specific preparatory exercises right from the beginning. Bondarchuck formulated from this conclusion his principle for the many-sided specific preparation theory. According to it, on the road from a beginner to a world class athlete, specific strength development exercises should be employed guided by the principle of "from the simple to the complicated".

Adaptations to the neural factors (intramuscular coordination) and hypertrophy that is developed during a strength training phase take place in opposing temporal directions (Fig. 4). Initial performance improvements are almost exclusively achieved from a better exploitation of neural factors, as well as the training effect on untrained extremities.