# THE USE OF ELASTIC ENERGY: A MATTER OF TIMING

**ELLIOTT, B.C.; WILSON, G.J.**
**Department of Human Movement and Recreation Studies**
**The University of Western Australia**
**Australia**

ABSTRACT

Twelve experienced male weight lifters completed a series of bench press lifts at 95% of their maximum. These lifts included a rebound bench press, a purely concentric bench press, and bench presses with a long and short pause between descent and ascent phases of the lift. Force, electromyographic and cinematographic data were collected from these lifts. The elastic energy stored during the eccentric phase of the lifts was observed to dissipate as a function of the pause period. This relationship was significantly ($p<0,01$) represented by a negative exponential equation with a 0.85 s half-life of decay. During the concentric phase of the RBP lift the stored elastic energy was quickly recovered and only assisted in the production of force for the initial 0.23s of concentric activity. The nature of this decay of elastic energy with increasing pause periods and the rapid dissipation of recovered elastic energy during the concentric phase are discussed with reference to their implication for performance of stretch-shorten cycle activities.

## INTRODUCTION

"Prepare early" is a common phrase used by coaches in hitting sports. The logic behind such a statement is that for the ball to be hit at the appropriate time and not "late" requires this early preparation. The question then arises as to whether performance is in fact hindered by this early preparation, as elastic energy stored during the stretch cycle of the movement (backswing) may not be of benefit during the shorten cycle of the activity (forward swing). This stretch shorten cycle is generally observed in sport as a counter-movement during the backwing or preparation phase of the activity (the stretching phase) that precedes the actual forward or upward movement (the shortening phase).

Biomechanical research has shown that the use of elastic energy has resulted in augmentation to performance derived from prior stretch. Asmussen and Bonde-Petersen (1974) observed a mean increase of 10.3% in total height jumped and Komi and Bosco (1978) observed a mean increase of 16.7% in total height jumped by skilled performers, both due to prior stretch. Bober et al. (1980) reported a mean augmentation to concenric velocity in a seated pushing movement of 13.7% due to prior stretch of the upper body musculature.

The purpose of this study was to examine changes in the augmentation to performance derived from prior stretch with increasing pause time in a bench press. Further, the timing of this augmentation with reference to the ascent of the bar will be determined.

## METHODS

### Subjects

Twelve experienced male bench pressers of varying ability, who were in current training, served as subjects in this study. Each subject performed four bench press lifts. These included a rebound bench press (RBP), a bench press with a short pause between the eccentric and concentric phases (SPBP), a press with a long pause between the eccentric and concentric phases (LPBP), and a purely concentric bench press (PCBP), where the movement was initiated from the chest, without prior stretch. All bench press lifts were then performed at 95% of a subject's perceived maximum for each condition.

The RBP was performed first by all subjects. Such a procedure was deemed necessary as the RBP is the lift most frequently undertaken by the subjects and therefore provided the most reliable examination of the accuracy of the subject's perception of their maximum. This allowed for slight modification of the loads to occur, based on the subject's strength level on the testing day. The order of performance of the remaining three lifts were randomized. Prior to lifting, each subject performed their standard warm-up, which included several sets of progressively increasing loads. Subjects were instructed to perform at as high force output as possible. All subjects were given as much recovery time between lifts as desired, and typically required a five to eight minute rest period.

The duration of pause for the SPBP and LPBP movements were subjectively determined by an experienced powerlifting official. The short pause was defined as a standard competition pause, while the long pause was defined as twice this duration. The pause duration were subsequently and accurately quantified by use of film data, as the epoch during which the bar remained in contact with the chest.

Ground reaction force procedures

Subjects performed the lifts on a bench which was designed to conform to International Powerlifting Federation standards and was rigidly mounted to a force platform (Kistler 9281B ) by four screws. The vertical and horizontal forces for each bench press movement were recorded. The analogue signals from the force platform were amplified and data collected on an IBM-PC compatible computer.

Filming procedures

All bench press movements were filmed at a nominal rate of 100Hz by a 16mm Photosonics high speed camera attached to a rigid tripod. The camera was positioned perpendicular to the sagittal plane of motion of the subject and bar. Cinematographic data were synchronized with the force data by use of a Dawe Stroboscope. Depression of a manual trigger to commence force data collection simultaneously activated the strobe light, which operated at 200Hz and was positioned in the camera's field of view.

Analysis and Treatment of Data

The vertical force, which was adjusted for bar weight, was combined with the horizontal force using Pythagora's Theorem to derive a resultant force. The augmentation due to prior stretch was quantified as follows:

$$\frac{\text{Bench press impulse}}{\text{PCBP impulse}} * 100 \%$$

where impulse was calculated over the first 0.37s of the concentric phase of each lift. This period was determined after examination of force-time and power-time curves of the PCBP and RBP lifts revealed that the augmentation to concentric motion derived from prior stretch was no longer evident 0.37s into the concentric motion for any lifter.

A second order Butterworth recursive low pass digital filter was used to smooth the position data at a cut off frequency of 5Hz. Velocity data were subsequently derived using finite difference calculus. The film data provided positional information which were used to delimit the bench press movement into its descent and ascent phases, and allowed quantification of the duration of the pause period. The velocity data, used in conjunction with force data, allowed for the calculation of instantaneous power of the bar (Wilson et al., in press).

The effect of the imposition of a pause between the eccentric and concentric phases on the utilization of elastic energy was examined by a one-way repeated measures analysis of variance between the various bench press conditions. If a significant ($p<0.05$) result was obtained, Scheffe's comparisons were used to identify which conditions were significantly different. The pause duration versus use of elastic energy data were also fitted to exponential models. The best model was determined by a minimization of least squares criterion.

RESULTS AND DISCUSSION

1. Dissipation of elastic energy due to the imposition of a pause.

The mean duration of the pause period for the SPBP was 0.6s while the LPBP had a mean pause time 1.3s. The effect of imposing these pause periods between the muscle stretch and shorten movement phases was to significantly reduce the impulse produced during the bar's ascent as compared to the RBP (Table 1)

TABLE 1
Relative Impulse Compared to Impulse for PCBP During Initial 0.37s of Concentric Motion (%)

| | X | SD | Significance ($p<0.01$) |
|---|---|---|---|
| RBP | 119 | 5 | RBP > SPBP and LPBP |
| SPBP | 112 | 4 | SPBP > LPBP |
| LPBP | 107 | 3 | |

The RBP lift produced on average 19% more impulse compared to that produced in the PCBP for the same time period. The SPBP produced 12% more impulse and the LPBP 7% more impulse, as compared to the PCBP lift. Thus the effect of imposing a pause was to reduce the use of elastic energy. The augmentation values for the RBP compared to the PCBP were similar to the mean increase of 16.7% in total height jumped due to prior stretch for skilled male jumpers (Komi and Bosco, 1978) and a mean augmentation to concentric velocity in a pushing movement similar to the bench press of 13.7% due to prior stretch of the upper body musculature (Bober et al.,1980).

It is evident that the use of elastic energy declined as a function of the pause duration. The dissipation of elastic energy with increased pause time is accurately represented ($p<0.01$) by a negative exponential equation with a 0.85s half-life of decay (Figure 1). This is substantially shorter than the 4s half-life suggested by Shorten (1987) for the decay of stored elastic energy in leg extensor muscles, but corresponds to data presented by Thys et al. (1975). Therefore after a delay period of approximately 1 s 55% of the stored energy is lost; after 2 s 80% of the stored energy is lost and after a 4 s delay almost all the stored energy is lost.

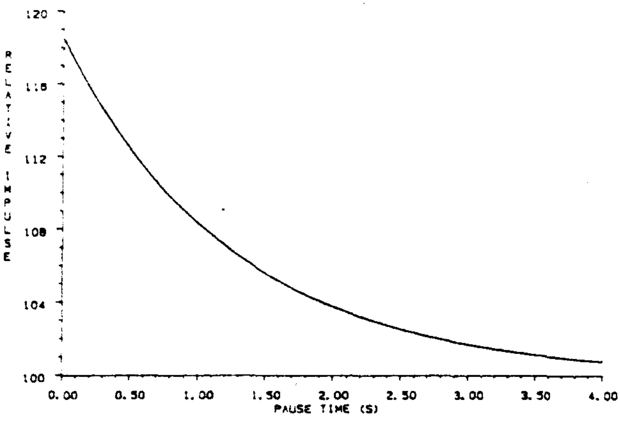


Figure 1: Dissipation of the use of elastic energy with increasing pause time

2. The dissipation of elastic energy throughout the concentric phase of the RBP lift.

The mean power-time curves of the PCBP and the RBP lifts (Figure 2) show that the recovery of elastic energy greatly facilitated the production of work over the initial portion of the concentric phase. However, the augmentation realized was short lived and in fact it was no longer evident approximately 0.23s into the concentric motion. This supported work by Chapman and Caldwell (1985) who reported that the influence of a prior stretch was no longer evident approximately 0.25 s into the concentric action.

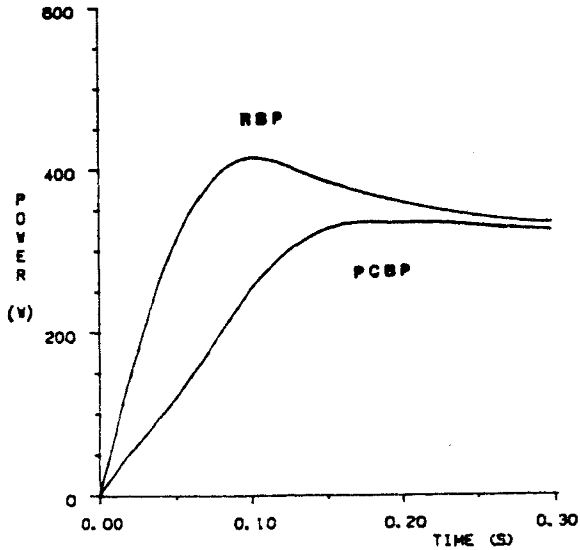

Figure 2: Mean instantaneous power curve for the first 0.3 s of bar ascent.

CONCLUSIONS

This study has not only shown that elastic energy is important in the bench press movement, but that its contribution to movement is reduced as the pause between stretch and shorten phases of a movement is increased. Coaches for best effect must aim to reduce this pause to as small a period as is practical while still maintaining an efficient technique. That is, in hitting skills the backswing and forward swing phases of movement must flow from one into the other. In movements where there is a sequencing of motion from the proximal to more distal segments then again the timing of the stretch phase of any of these joint actions must be such that the pause prior to movement is reduced. That is in a tennis serve, the player who prepares "too early" and is forced to wait for the ball will generally not benefit from the elastic energy stored in the muscles during the stretch.

In power lifting it is obvious that lifters must practice the bench press with a pause to replicate competitive conditions. Equally in events such as the clean and jerk it is important in the "clean" section of the lift to utilize the elastic energy stored during the squatting action to assist in the movement to an upright position. That is the smaller the pause at the bottom of the squat action the more elastic energy can be used to augment the upward motion.

It is also evident that this elastic energy has an almost immediate influence on the concentric motion. Consequently large accelerations can often be achieved in the early phase of the concentric motion if elastic energy is utilised; which may play a vital role in the early stages of a movement where the inertia of an object must be overcome or a skill can be performed with the assistance of augmentation from the elastic energy despite the body being in a mechanically poor position.

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