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Case Study: Resistance Training

MOVING TOO RAPIDLY IN STRENGTH TRAINING WILL UNLOAD MUSCLES AND LIMIT FULL RANGE STRENGTH DEVELOPMENT ADAPTATION: A CASE STUDY

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ABSTRACT

Johnston BD. Moving Too Rapidly In Strength Training Will Unload The Muscles And Limit Full Range Strength Development Adaptation. ***JEP****online*. 2004;8(3):36-45. Recommendations vary significantly in regard to how slowly or quickly a person should exercise when strength training, ranging from ballistic/explosive to the Superslow® protocol of 10 s concentric and 10 s eccentric. The purpose of our experiment was to determine the degree of forces produced and experienced by the tissues, by way of a digital force/strain gauge and computer plotting software, when moving under various conditions. It was concluded that there is little difference in the forces generated or experienced until trainees attempt to move a load explosively, to which forces increased by as much as 45 % initially, then decreased by 85.6 % for the majority of a repetition's tension time. With these findings it is apparent that trainees need to move slow enough to maintain tension throughout an exercise's range of motion and to avoid the higher forces experienced with explosive training and the consequential increase of tissue injury.

Key Words: Force Gauge, Cadence, Momentum, Muscle Tension.

INTRODUCTION

A common recommendation in the strength training field is the promotion of explosive movement and ballistic/explosive movement, the former of which refers to accelerating a resistance as quickly as possible, whereby the latter (viz., the concept of 'ballistic') refers to implementing stored energy of the stretched tissues to rebound a load, followed by rapid acceleration. Regardless of the philosophical reasons for particular training methodologies, what is questionable are the results and safety with slow to moderate velocity, controlled strength training as opposed to explosive or ballistic/explosive strength training. Many studies have demonstrated that there is no difference in strength and power gains from slow as opposed to explosive training, yet there are studies that do contend that superior results can be achieved with slower training methods, likely because of the constant tension maintained on the muscles throughout an exercise's range of motion.

Mikesky et al. (1) concluded that slower training produces better gains in hypertrophy, and Newton and McEvoy (2) found that slow resistance training improved baseball throwing velocity and bench press (6 RM) ability, whereas explosive medicine ball throws showed no improvement in baseball throwing velocity and inferior improvement in bench press ability. It is obvious that bench press ability would not improve much with medicine ball throwing, as per the Principle of Specificity, but the lack of results in throwing a baseball contradicts the popular philosophy that explosive exercise will enhance explosive sporting activities. Another study by Westcott et al. (3) demonstrated that slower movements (five 10 s concentric, one second pause, 4 s eccentric reps/set) in strength training likewise produced greater strength gains than with a shorter cadence (ten 2 s concentric, 1 s pause, and 4 s eccentric reps/set). The results were based on improved exercise performance, and not by other means of testing net muscular force.

It has been hypothesized that slower movements produce greater strength (and inevitable power) gains than moving quickly, likely because of greater and more consistent tension throughout the exercise's range of motion, and possibly rightly so. Nevertheless, to date this has not been explored sufficiently insofar as producing graphical representations of actual occurrences in muscle action. The quantification of muscle force development during contractions of different velocities can improve our understanding the implications of moving 'slow enough' as opposed to 'too fast' when prescribing an effective and safe exercise regimen. Consequently, the purpose of this study was to develop and record an experiment to determine the forces that transpire under different conditions of velocity, acceleration, and cadence protocols for a select muscle action (exercise) condition.

METHODS

Subjects

With 25 years experience that has included several of the most common exercise methods, such as high-intensity, traditional high volume, bodybuilding, power lifting and Olympic lifting, the author was used as the test subject. The use of a highly-experienced exercise enthusiast would guarantee better consistency and accuracy in exercise performance, consistent mechanics and testing quality than would a random subject with minimal or modest experience.

Procedures

The cable shoulder press was the exercise of choice, as depicted in the photo sequence below. The shoulder press is a common exercise to develop the shoulder and triceps for sport improvement that involves extension of the arm, such as shot putting and the throwing of a football or basketball, for example. The cable press version of this exercise allowed for the attachment of a strain gauge load cell (225 kg capacity) between the handle and the cable. The recorded force gauge data points, plotted using the WinWedge software (12-points/s collected; data searched and recorded every 50 ms) by way of the Dillon Quantrol AFTI digital force gauge (±0.1% accuracy with a peak capture rate of 2,000 Hz that is sensitive to 0.01 kg of force), began in the extended position (Figure 1 left photo), brought to the bottom position (middle photo), and then lifted to the extended position (right 3); from eccentric to concentric. The distance travelled was 61.5 cm, although closer to 66.7 cm with the ballistic/explosive protocol as the arm and shoulder pulled back to increase and implement the resultant stored energy.

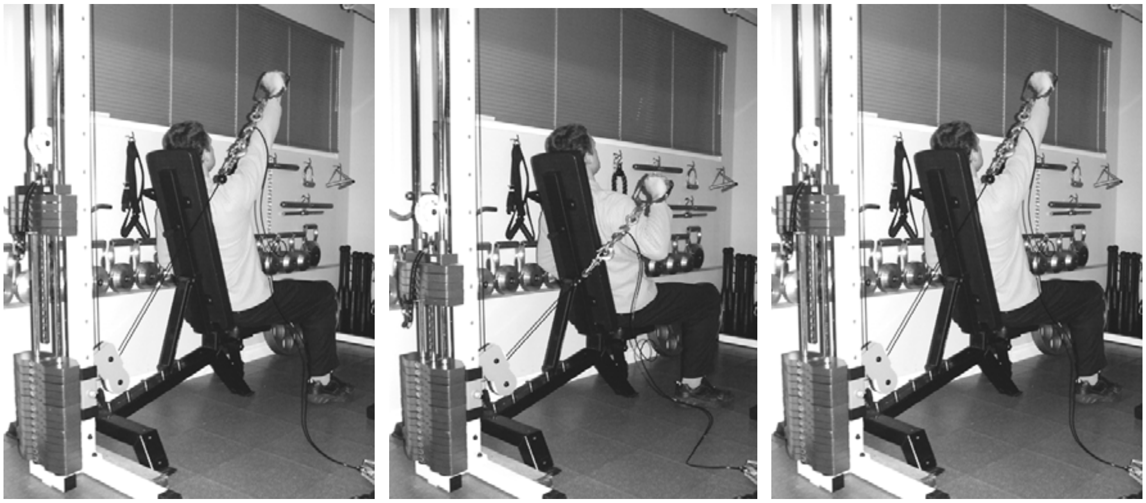

Figure 1. Photo sequence showing the action for the seated shoulder press.

The protocols tested with this exercise and presented in this paper, are as follows:

- Superslow® protocol of 10 s down and 10 s up.
- A reduced protocol of 5 s down and 5 s up.
- Nautilus protocol of 4 s down and 2 s up.
- Explosive protocol that involved accelerating the resistance up as quickly as possible to the top position, after a controlled 2 s eccentric phase.
- A ballistic protocol that involved lowering the resistance in approximately 2 seconds, rebounding from the stretched position, and then accelerating the resistance as quickly as possible to the top position.

The resistance used (including the weight of the load cell/force gauge hardware and cable handle) was 15.4 kg. It should be noted that explosive and ballistic training often employs lighter resistance than slower, controlled training, to allow for greater acceleration. However, to maintain consistency among the protocols, the same resistance was used, which was a light load for the test subject's ability and approximated 52 % of his 1 RM on that exercise. A heavier resistance was not used because of the increased risk of injury that is inherent with explosive and ballistic styles of exercise.

Also, two minutes of recovery were included between each protocol lift, to eliminate any fatigue, no matter how minimal, that could influence the subject's performance and/or mechanics among tests.

The subject was seated on a bench with a back support, with his legs and opposite arm relaxed to avoid body position changes. This allowed the recording of only the measure of forces and momentum that arose directly from the extended arm and shoulder or, at least, with as much control as was possible under the conditions. Certainly the measure of forces generated and experienced would be greater if the subject was allowed to employ extraneous muscle activity, as is common with explosive and ballistic styles of exercise.

RESULTS

Figure 2 presents the raw data fro one subject and shows some initial disorder as the subject moved into place. He then lowered the resistance for 10 s, which depicts a wavering force between 12.61 kg and 13.43 kg (approx. data points 23-143). Less muscle force is required to lower the resistance of 15.4 kg because of minor machine friction and, otherwise, the weight would not lower, but remain static or rise. When the resistance was lifted, both the amount of muscle force and the resistance were nearly equal (a maximum of 15.74 kg at one point). Some disorder is shown after data point 232 as the subject lowered the cable handle to his side.

Also of note is the erratic line produced by the subject, a result of exercising against a resistance in an unstable environment (typical with cable exercises) and as the muscles work to find the center of balance within a plane of movement. Movement is never perfectly smooth, although a much smoother line (albeit still erratic to some extent) would be produced if exercising on a machine with a controlled path. In effect, and particularly when moving slowly, the muscles are in a constant state of flux, between acceleration and deceleration in an attempt to control velocity relative to time, and the faster one moves, the smoother a force curve would appear when measured and plotted.

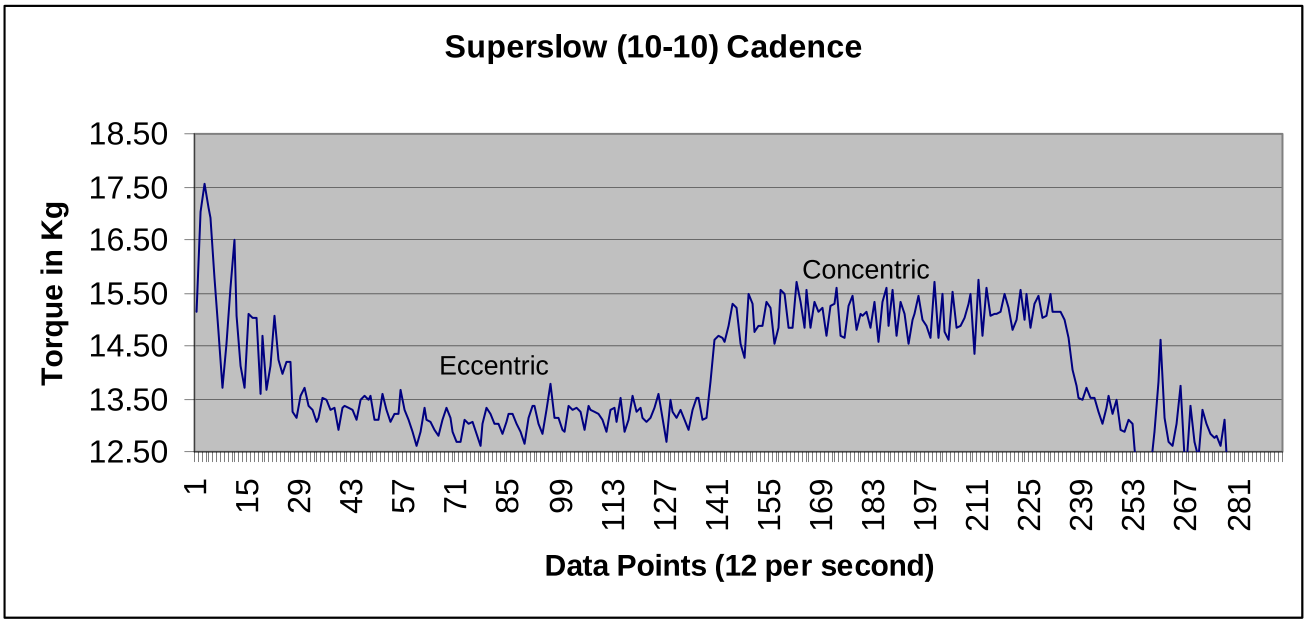

Figure 2. The continuous output from the strain gauge during an exercise sequence, using a 10-10 s protocol as described for Figure 1.

Tested next was a cadence at a value of half the rate of movement (5s - 5s), as shown in Figure 3. At a 5-5 cadence, the eccentric portion of the movement can be seen between data points 18 and 78 (once the subject ‘settled in’), with forces that fluctuated between 12.11 kg and 13.88 kg. The concentric portion of the movement (approx. data points 78 to 130) averaged near 15.5 kg, but resulted in a maximum force of 16.06 kg; 0.32 kg greater than the highest force recorded with the 10-10 protocol. From this information, it was determined that there is very little difference in force produced/experienced by the muscles whether moving at a 10-10 or 5-5 cadence, and one protocol appears to provide as much tension on the muscles (and safety) as the other.

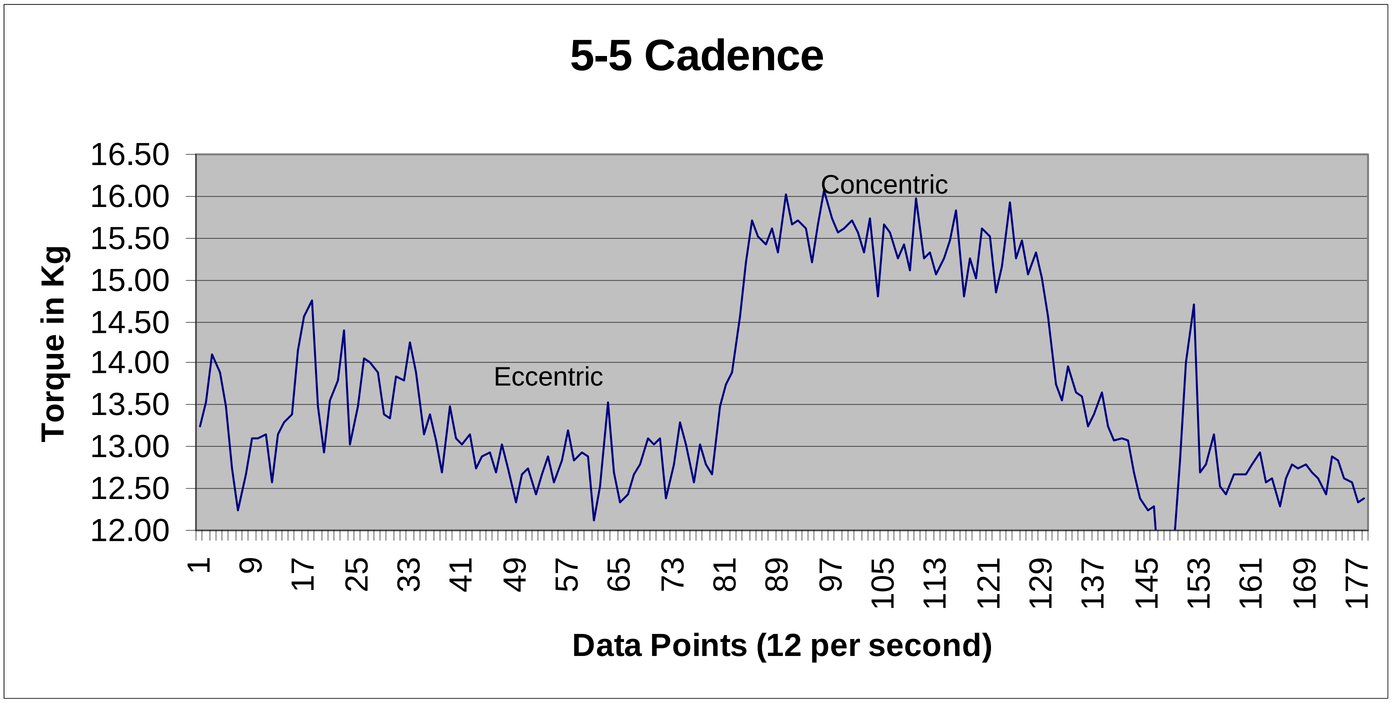

Figure 3. The continuous output from the strain gauge during an exercise sequence using a 5-5 s protocol, as described for Figure 1.

Another common cadence prescription is the Nautilus protocol of four s eccentric and two s concentric (4-2 protocol), as illustrated in Figure 4. Data points 30-72 represent the 4 s eccentric phase, and a force that fluctuated between 12.21 kg and 13.34 kg (less force overall than the eccentric of either the 10-10 or 5-5 protocol, which indicates less muscle activity is required to lower a weight quickly than to control its descent more slowly). The 2 s concentric phase (data points 72-96) had a peak force of 16.47 kg, or about 0.73 kg more than the weight used. This peak force also was only 0.41 kg greater than experienced with the 5-5 cadence, and 0.73 kg greater than experienced with the 10-10 protocol.

The next protocol involved explosive movement from a ‘dead stop’ position, at the bottom of the cable shoulder press and after an eccentric phase of 2 s. As revealed in Figure 5, there is less consistency with explosive training, since the amount of force produced on each repetition is affected by fatigue and motivation to accelerate a load as hard as possible. Two repetitions were recorded with that in mind, shown below, with a peak force of 24.64 kg exerted on the first repetition to move the 15.42 kg load at a maximal velocity.

The concentric portion of the movement lasted less than 1 s, and during that time, the working muscles experienced very little tension throughout the full range of possible movement, as shown by the dramatic force decrement to a low of 5.08 kg during the second repetition.

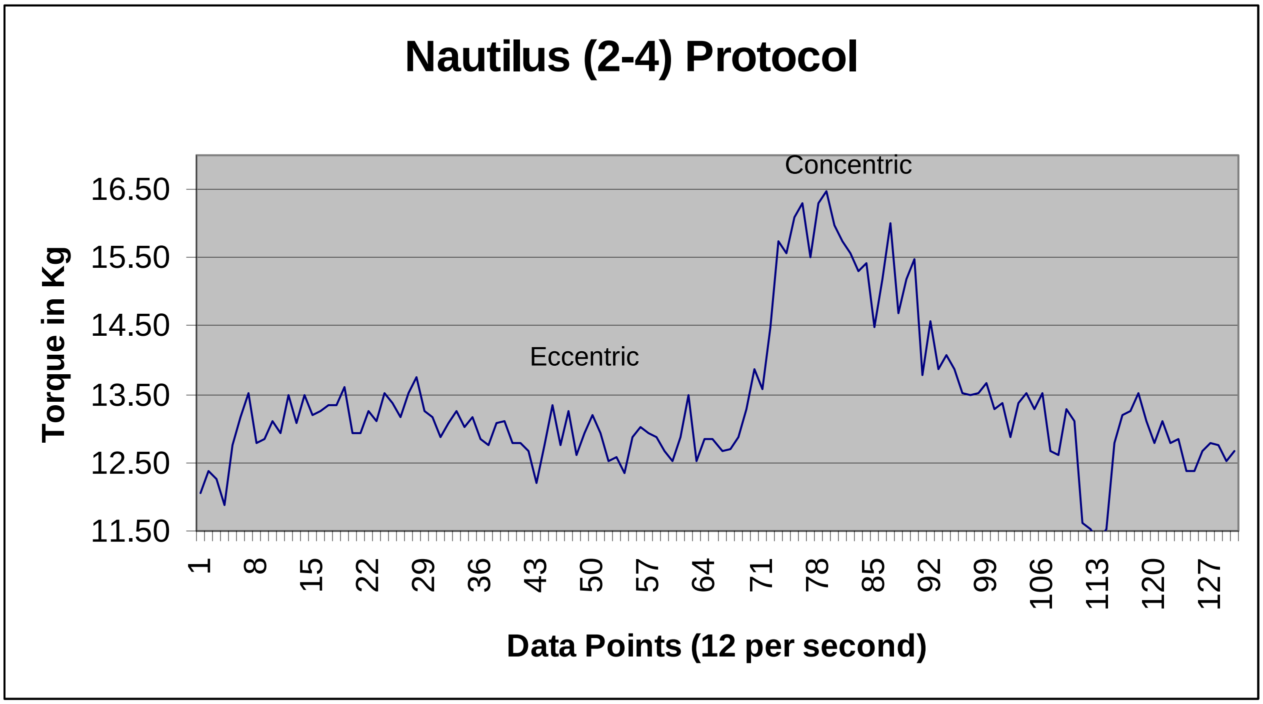

Figure 4. The continuous output from the strain gauge during an exercise sequence using a 2-4 s protocol, as described for Figure 1.

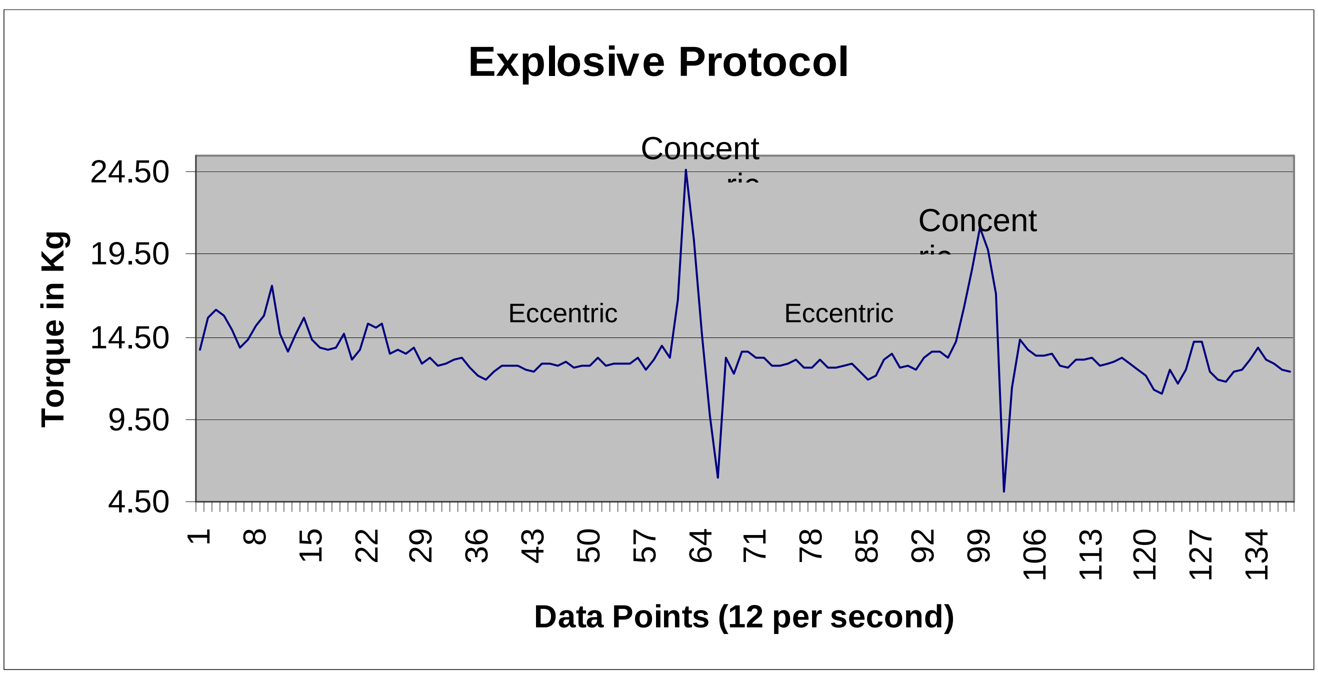

Figure 5. The continuous output from the strain gauge during an exercise sequence using an explosive protocol, as described for Figure 1.

Figure 6 presents that data from four repetitions performed with a rebound at the bottom position and then accelerated with maximum effort. The highest level of force occurred on the fourth repetition at 28.63 kg, and a low level of force on the first repetition at 2.2 kg. As with the previous graph, the low points are the result of the resistance being propelled upward (by use of stored energy [non-muscular torque] and momentum). Due to the momentum, muscular force development is reduced (nearly eliminated).

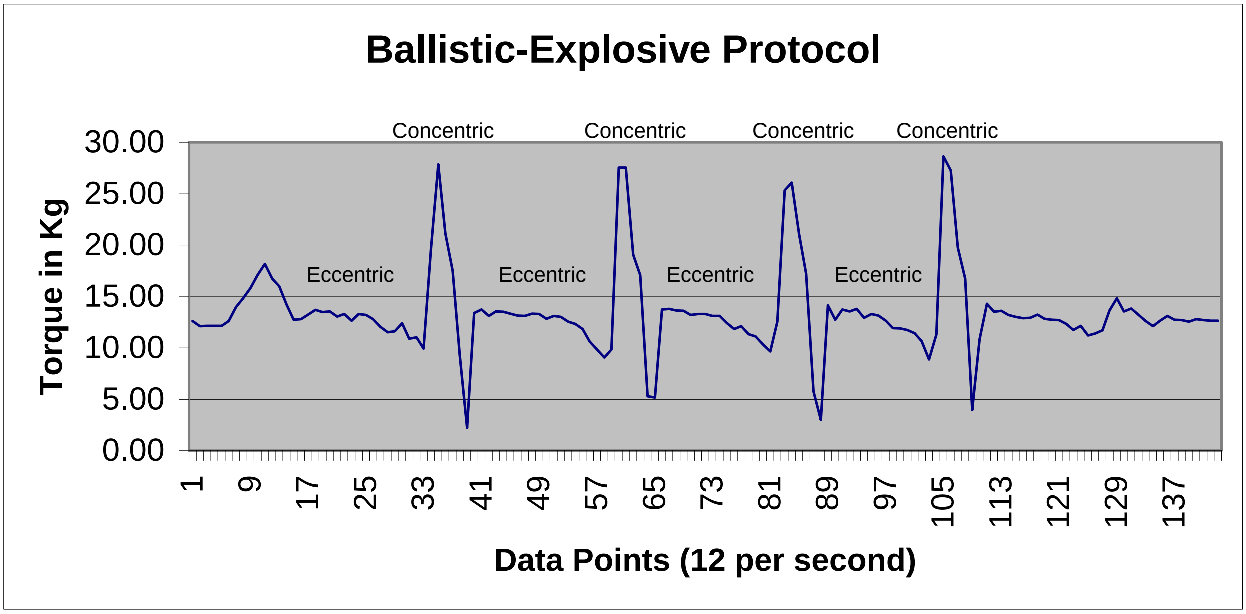

Figure 6. The continuous output from the strain gauge during an exercise sequence using an explosive-ballistic protocol, as described for Figure 1.

Table 1 indicates the lowest, highest and mean forces during the concentric phase of each protocol. The explosive and ballistic-explosive protocols include the lowest and highest forces registered among the repetitions performed.

Table 1. The lowest, highest and mean forces during the concentric phase of each protocol.

Protocol	*Lowest Concentric Force*	*Highest Concentric Force*	*Mean Concentric Force*
Superslow 10-10	14.29 kg	15.74 kg	15.02 kg
5-5	14.79 kg	16.06 kg	15.43 kg
Nautilus 4-2	15.74 kg	16.47	16.11 kg
Explosive	5.08 kg (2nd repetition)	24.64 kg (1st repetition)	14.86 kg
Ballistic-Explosive	2.22 kg (1st repetition)	28.63 kg (4th repetition)	15.43 kg

DISCUSSION

From this data it can be seen that there is little difference, in regard to forces produced/experienced and the issue of safety (i.e., potential for injury as a result of unwanted and excessive forces) between the 10-10, 5-5 and 2-4 protocols. However, it should be noted that the above is true only if body mechanics and quality of form (including cadence timing) remain consistent from the beginning to end of a set and among all repetitions and among the protocols, which is not the case always, and particularly with complex free-weight movements, such as the squat. And sometimes it is not the measure of force changes that are a safety concern, but the distribution of forces along the tissues as mechanics alter. Consequently, it may be best to error on the side of safety and move 'slow enough' or slower than 'one thinks one should' to avoid unusual or high forces, and to be aware of proper form throughout a set of exercise. Certainly an experienced trainee could control these factors more effectively.

What also is apparent is that moving faster, and at some critical point, greater (noticeable and perceivable) forces must be produced to travel the same distance of ROM, i.e., to move a weight from point A to point B. In this instance, that critical limit is approximately 2 s, and relative to the exercise movement of a shoulder cable press. All of this should be obvious since greater acceleration, in order to cover the same distance in less time, will necessitate greater muscular force. Certainly more force is required to move at a cadence of 5-5 than 10-10, but the differences seem to be almost negligible, and perceivable only when reaching a particular threshold, as demonstrated with a 4-2 cadence, for example.

Once movement becomes rapid, as with explosive strength training techniques, forces increase significantly (upward of 33.1 % greater when compared to the highest force among the 2-4, 5-5 and 10-10 protocols), and it appears that the only area of the exercise's ROM that receives sufficient tension is at the beginning of the movement, just as the muscles exert a maximum force (and at the tissues' weakest and most vulnerable point for injury!). Thereafter, tension reduces to such an extent that a serious athlete or weight trainee would not even consider the load appropriate for a warm-up, let alone a work set. In this case, a low of only 5.08 kg of force was experienced for about 75 % of the movement's range.

Ballistic/explosive exercise appears to involve even less muscle tension throughout an exercise's full ROM, yet even greater forces upon initial movement at the bottom, stretched position (upward of 42.47% greater forces when compared to the highest force experienced among the 2-4, 5-5 and 10-10 protocols), partly as a result of stored energy and not muscular force. This means less muscular tension throughout the exercise's full range of movement (and strength developing results) and a higher risk of injury.

It has been suggested that athletes who utilize or require stored energy within their respected sports, such as a shot-putter, pole-vaulter, or javelin thrower, would benefit from ballistic-type exercise in the weight room. However, the specific mechanics, neurological patterns, and degree of activation among muscles during any strength training movement are non-specific to the sporting examples provided. In effect, enhancing one's ability through strength training is different than demonstrating that ability in *unlike* activities that require different mechanics, skills and application of one's strength, power and quickness, as per the Principle of Specificity. This conclusion has been supported repeatedly in the field of neurophysiology, as far back as 1949 (4), and which suggests that any degree of possible carryover from ballistic-type exercise to sports is no more relevant than slow, traditional strength training coupled with sport specific skill training (i.e., activity that incorporates *specific* ballistic adaptation and application). Consequently, the increased risk of injury that is inherent with higher force, ballistic and explosive strength training must be considered and given precedence when developing an exercise program for athletes worth millions of dollars.

Moreover, the requirement for full range strength training to obtain full range strength benefits has been accepted by some and questioned by others. What we have discovered at our testing and training facility is that the ability to improve in strength at all angles often results in the need to exercise all angles, although in some instances full range changes are possible with partial range exercise. Either of which depends on the individual and his or her muscle in question. However, even in those muscles that do produce full range results at all joint angles, with partial range exercise, the greatest changes do occur with direct exercise at a specific joint angle trained.

These findings have been supported by the research conducted by MedX Inc. and the Medical Department at the University of Florida (5) when each tested subject was considered individually. Similar results have been determined by Graves et al. (6), insofar as their subjects having produced the *best* results at a particular joint angle when exercising that particular joint angle, although full range benefits were produced to some extent even with partial range exercise. The Graves study likely would have concluded similar and varied results as we have and that of the University of Florida's research if each subject was considered rather than averaged within a group. As a research study colleague stated, "group data can always mask inter-individual differences." (7)

In effect, if explosive and ballistic/explosive exercise produces a high amount of tension at the onset of a movement, but with significantly decreased tension for the majority/remainder of the movement, it may be concluded that such training style does not produce full range strength results or, at best, inferior full range strength results when compared to moving "slow enough" to maintain a constant tension throughout the movement's exercised range. Certainly this needs to be considered, besides the fact of the increase of injury caused by rapid movement while strength training.

CONCLUSIONS

This experiment was undertaken to discover just how much momentum is involved in an exercise (the cable shoulder press) at different rates of movement and the duration of which momentum exists. This is an important factor since, in effect, if muscular change is partly the result of the muscular work stimulus, and if there is little work imposed on the muscles, then there would be little or no stimulus to produce positive change in muscular strength. Therefore, improvement in muscular strength, and particularly at specific joint angles (an important issue for athletes looking to enhance and fine-tune power output at particular body positions), requires deliberate and controlled strengthening exercises rather than ballistic/explosive activity, the latter of which emphasizes *reduced* muscular activity (net muscular force) by way of *increased* momentum and stored energy.

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