UNDERSTANDING AND OPTIMISING PLYOMETRIC TRAINING

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Plyometrics are exercises involving rapid, powerful movements preceded by a preloading countermovement. The stretch shortening cycle (SSC) is the basis of plyometric exercises. The precise mechanisms that underpin any SSC activity may be determined by the demands of the criterion task. As a result the SSCs can be classified as slow or fast. Accordingly, different plyometric exercises or the manner in which exercises are performed may elicit different mechanisms of SSC action. Slow SSC plyometrics are useful to teach athletes appropriate jumping and landing techniques and to develop maximal jumping ability. Fast SSC plyometrics develop athlete's ability to generate high power outputs and fast rates of force development.

KEY WORDS: force, jumping, reactive strength index.

INTRODUCTION & OVERVIEW: Plyometrics are exercises involving rapid, powerful movements preceded by a preloading countermovement. Examples of plyometrics include depth jumps, hurdle jumps and bounding. Plyometric training has been shown in the literature to have a number of beneficial effects for athletes. These range across injury prevention, power development, sprint performance, agility development, and running economy. Little to no morphological changes occur in response to plyometric training. The adaptation which takes place is primarily on a neural level (Markovic et al., 2005).

The stretch shortening cycle (SSC) is the basis of plyometric exercises. The SSC is a natural type of muscle function in which muscle is stretched immediately before contraction. This eccentric/concentric coupling of muscular contraction produces a more powerful contraction than that which would result from a purely concentric action alone (Komi, 1992). In real-life situations, exercise seldom involves a pure form of isometric, concentric, or eccentric actions (Komi, 2000). The SSC appears to be the natural form of muscle function, and it is evident in everyday activities, such as running, throwing and jumping.

A number of biomechanical mechanisms are thought to contribute to the SSC. It has traditionally been thought that the SSC causes an enhancement during the concentric phase due to the storage and reutilization of **elastic energy** (Cavagna et al., 1968). During the eccentric phase, the active muscles are pre-stretched and absorb energy. Part of this energy is temporarily stored and then reused during the concentric contraction phase of the SSC (Bobbert et al., 1996). A short transition between the eccentric and concentric phase is necessary for this elastic energy to be used optimally.

Additional mechanisms of action also have been proposed. It has been proposed that the prestretch in the SSC may enhance the concentric contraction through **neural potentiation** of the muscle contractile machinery during the eccentric phase. This would allow for a greater number of motor units to be recruited during the concentric contraction (Van Ingen Schenau et al., 1997). This potentiation effect is thought to increase with the speed of the eccentric action and is maximised when a short transition time between the eccentric and concentric phases occurs (Bobbert et al., 1987a).

Bobbert et al. (1996) determined that in tasks such as maximal effort vertical jumps, in which eccentric-concentric coupling is used compared with purely concentric squat jumps, the performance enhancement in the SSC is likely caused by the eccentric phase, allowing **an increased time to develop force**. A slow eccentric phase allows muscles to develop a high level of active state (more attached crossbridges) before the start of concentric action. As a result, developed force and joint moments are greater at the beginning of the concentric phase and more work is produced through the first part of the concentric motion compared to concentric only squat jumps.

Reflex contributions of the muscle spindle mechanoreceptor can also contribute to the enhanced work output observed in the SSC. **The muscle spindle reflex** reacts to rapid changes in a muscle's length to protect the muscle–tendon complex. As eccentric stretching

approaches a rate that could potentially damage the muscle–tendon complex, the muscle spindle activates and reflexively stimulates an opposite contraction of the agonist. Contributions from the muscle spindle are one mechanism that accounts for the performance enhancement observed in SSC activities which involve very rapid eccentric phases (Bobbert et al., 1987b).
The precise mechanisms that underpin any given SSC activity may be determined by the demands of the SSC criterion task (Flanagan et al., 2007). For example:

- For the muscle spindle reflex to be initiated, a fast rate of eccentric stretching must occur.
- For elastic energy to contribute, there must be a short transition period between the eccentric and concentric phase
- For neural potentiation to contribute there must be a fast eccentric phase and a short transition period between the eccentric and concentric phase.
- In order to allow an increased time to develop force, the eccentric phase must be slow.

Considering this, Schmidtbleicher (1992) has suggested that the SSC can be classified as either slow or fast. The fast SSC is characterized by short contraction or ground contact times (<0.25 seconds) and small angular displacements of the hips, knees, and ankles. A typical example would be depth jumps. The slow SSC involves longer contraction times (>0.25 seconds), larger angular displacements and is observed in maximal effort vertical jumps. Data from Flanagan and co-workers (2007) have shown that slow SSC actions such as maximal effort countermovement jumps generally produce ground contact/contraction times far greater than Schmidtbleicher's (1992) threshold of 0.25 seconds and that the difference between slow and fast SSC activities is easily discernable.

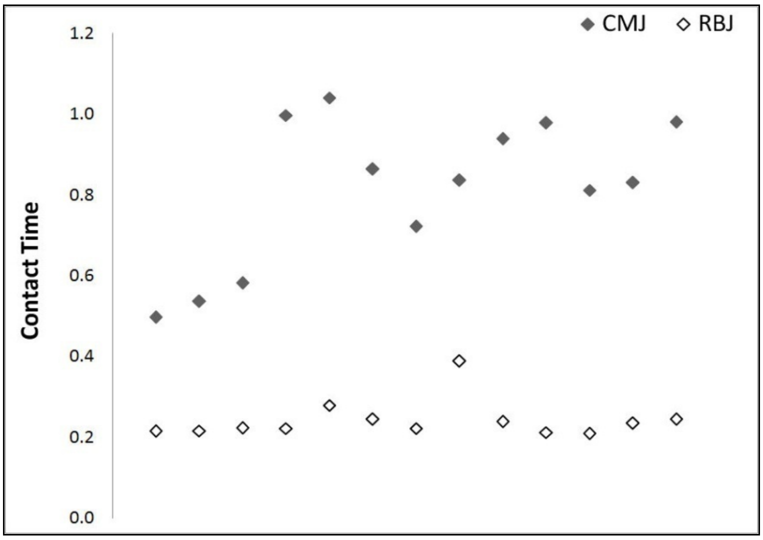

Figure 1: Data from Flanagan et al. (2007). Each subject produces significantly shorter ground contact/contraction times (s) in the fast SSC action of the rebound jump (RBJ) compared with the slow SSC action of the countermovement jump (CMJ).

For example, the muscle spindle reflex is dependent on a fast rate of eccentric stretching and elastic energy contribution may rely on a short transition period between eccentric and concentric phases (Bobbert et al., 1987a). Decay in the magnitude of potentiation has been observed as the transition time between eccentric and concentric contraction increases (Wilson et al., 1991). These mechanisms then are more likely to contribute to the fast SSC which has a faster eccentric velocity and a shorter transition period than the slow SSC (Bobbert et al., 1987a).

Performance enhancement in slow SSC activities may be primarily due to the slow eccentric phase allowing an increased time to develop force (Bobbert et al., 1996). The slower, longer eccentric phases and the greater transition times between eccentric–concentric coupling observed in slow SSC activities cast doubt as to whether mechanisms such as the muscle spindle reflex, elastic energy contributions, and potentiation could be as active in slow SSC tasks compared with fast SSC activities (Flanagan et al., 2007). As a result, it has been hypothesized that the slow and fast SSC may represent different muscle action patterns that rely on differing biomechanical mechanisms, which can affect performance in different ways (Flanagan et al., 2007).

The primary differences between the fast and the slow SSC are that the fast SSC involves a fast, short eccentric phase and a rapid transition between the eccentric and concentric phase. The slow SSC is identifiable by a longer eccentric phase and a slower transition. The magnitude of potentiation increases dependent on the speed of the eccentric phase and decreases with transition time (Bobbert et al., 1987a). As a result much greater joint moments, power outputs and rates of force development are observed in fast SSC plyometrics. Alternatively, greater jump heights can be observed in slow SSC plyometrics due to the increased time allowed to develop force. Slow SSC plyometrics are also very useful coaching tools to teach athletes appropriate jumping and landing techniques before progressing to the more challenging fast SSC plyometrics.

This has implications for strength and conditioning practitioners. Different exercises or the manner in which exercises are performed may elicit different mechanisms of SSC action. Training slow SSC activity may not by as beneficial for athletes who primarily rely on the fast SSC in their chosen sports (and vice versa). To adhere to the principle of specificity, coaches must be able to distinguish which plyometric exercises utilise the fast or slow SSC. Careful consideration must be made to select modes of training which incorporate the appropriate SSC action for the athlete’s specific needs.

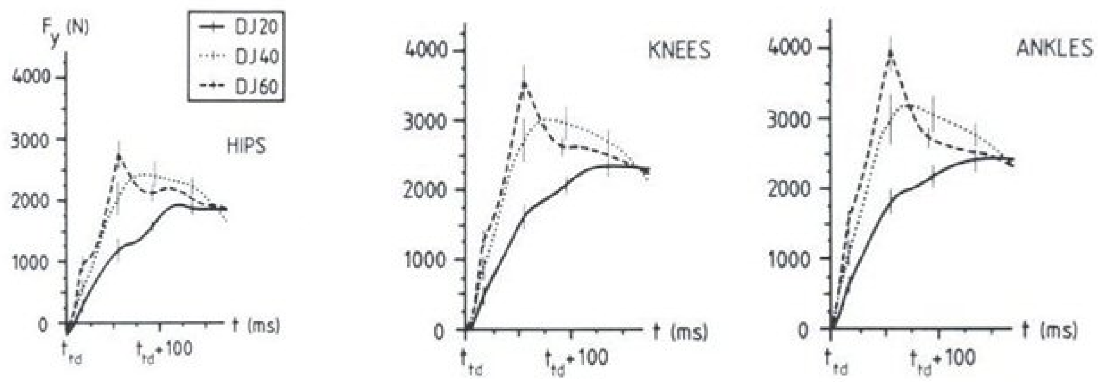

Figure 2: Data from a single subject in Bobbert et al. (1987a). Peak joint reaction force is recorded at the hips knees and ankles during depth jumps from heights of 20, 40 and 60cm.

Due to the greater forces, joint moments and power outputs which occur in fast SSC plyometrics there is a degree of injury potential if training is not carried out sensibly. Bobbert et al. (1987b) provided some data describing one process through which the inappropriate use of fast SSC plyometrics could potentially cause injury.

In this research, subjects performed depth jumps from heights of 20, 40 and 60cm. Joint reaction forces were recorded during the jumps at the hips, knee and ankle. In depth jumps subjects are instructed to minimize ground contact times, to utilize the fast SSC. To do this they use a stiff leg action and stay on the balls of their feet. Bobbert et al. (1987a) observed that certain depth jump heights (60cm in this case) can be too great. At an athlete’s critical threshold, the downward velocity becomes too great and the athlete can lack the requisite strength to overcome this eccentric loading and transition effectively to a powerful concentric phase. As a result, Bobbert et al. (1987a) report that subjects were unable to stay on the balls of their feet and their heels came down on the ground. This caused sharp peak forces to be generated resulting in high joint reaction forces at the ankle, knee and hip. These sharp, high joint reaction forces can potentially cause damage to passive structures such as the joint surfaces.

This is not optimal from a safety perspective but also, from a training effect standpoint, can violate the principle of specificity. With subjects unable to react against the high eccentric velocities, their heels come down to the ground and they spend longer on the ground in order to generate enough force to perform the concentric phase. This elongation of the ground contact phase may mean the athlete is now performing a slow SSC movement when the objective of training may be to improve fast SSC performance.

PRACTICAL APPLICATION: Coaches must be able to identify poor technique and choose appropriate training intensities in fast SSC plyometrics to optimize the training from both a safety and performance perspective. The practical portion of this presentation will demonstrate the following:

- the differences between slow and fast SSC plyometric exercises.
- how slow plyometrics can be used to train proper jumping and landing techniques.
- the appropriate execution of fast SSC plyometric exercises.
- how fast SSC plyometrics can be progressed and increased in intensity.
- how slow and fast plyometrics can be used in tandem with training sessions.

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