INCREASES IN SEGMENT OR IMPLEMENT VELOCITY: A BIOMECHANICAL PERSPECTIVE

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The coach, who both understands the mechanical aspects of a skill, can analyse movement and is also able to communicate with athletes will provide the best opportunity for optimal development. The same coach will however, often be posed the question of how to enable pupils to develop higher velocities in hitting/kicking or body movements such that they are able to develop a higher velocity, while still maintaining an acceptable level of control.

This paper introduces five important bioinechanical considerations, integral to the teaching of high velocity movement. A brief review of the research papers in each of these areas will provide sport biomechanists with a theoretical framework for velocity development that can be presented to coaches. This will assist coaches to understand how to modify technique to produce higher segment or implement velocities.

1. THE USE OF ELASTIC ENERGY

"Prepare early" is a common phrase used by coaches. 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 any movement may not be of benefit during the "shorten cycle" of the activity. Research has shown that both increasing the speed of the stretching phase and resisting the stretching movement by applying greater tension in the muscle(s) being stretched enhance the storage of elastic energy (Shorten, 1987). On movement reversal, during the shortening phase, the stretched muscles and tendons recoil back to their original shape and in so doing a portion of the stored energy is recovered and assists the movement.

Research has shown that the use of elastic energy accounts for approximately 50% of the total energy requirement of running (Cavagna et al., 1964); 12% of the total height attained in a vertical jump (Asmussen and Bonde-Petersen (1974); and 19% of the weight capable of being lifted in a bench press (Wilson et al., 1991A). The key to the recovery of this elastic energy is the timing between the stretch-shorten cycle. The benefit of this stored energy is reduced if a delay occurs between the stretch and shorten cycles of the movement. In the bench press, after a period of approximately 1 s, 55% of the stored energy was lost, after 2 s 80% of the stored energy was lost and after a delay of 4 s, effectively all the stored energy was lost (Figure 1).

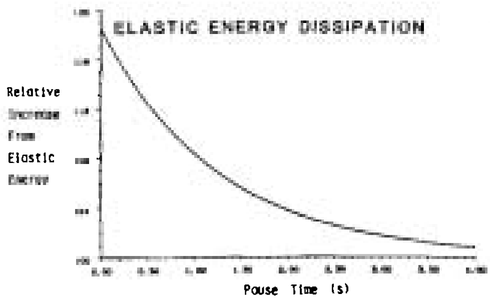

Figure 1: The loss of elastic energy with increased pause time (modified from Wilson et al., 1991A).

The recovery of this stored energy occurs relatively quickly and is thus a major benefit early in the forwardswing phase of the swing or in movement to the ball. Chapman and Caldwell (1985) reported that all elastic energy had been released 0.25 s into the shortening phase of a forearm rotation movement, while Wilson et al. (1991B) reported that the majority of stored energy in the bench press had been released 0.2 s into the shortening phase. This is of major benefit to young children who may often need the assistance of this energy source to overcome inertia of an implement or to adults during the early part of a forward movement in that the completion of the backswing is often a poor mechanical position to apply force.

Practical Implications For Coaches: Players may be taught to:

* Flow the backswing and forwardswing phases of hitting or kicking skills from one phase of movement to the other.
* Utilise the benefits of plyometric training which while enabling athletes to overload their musculature in positions and at velocities similar to the competitive situation, may also enhance an athlete's ability to store elastic energy (Bosco et al., 1982).

2. THE DISTANCE OVER WHICH VELOCITY CAN BE DEVELOPED

One of the main reasons for having a backswing or a series of preparatory movements in an activity is to increase the distance over which velocity can be developed during the forwardswing. The potential to generate velocity over this increased distance will only occur if the time needed to perform the activity does not increase proportionately.

In a straight backswing (often taught to beginners) the implement (i.e. bat or stick) is taken back in a relatively straight line, before stopping in the backswing position, prior to then swinging forward to the ball. This backswing, which is easy to learn, is very good in developing ball control, however, the distance the implement or limb moves forward to the ball is often not sufficient to allow the development of a high velocity at impact.

The looped or curved backswing was developed in activities such as in a groundstroke and serve in tennis, a golf drive or a baseball pitch. The rotation of the lower limb in preparation for a kick increases the distance over which velocity can be developed during the forwardswing to the ball.

Practical Implications For Coaches: Players may then be taught:

* To use a looped or curved backswing to increase the velocity potential of the forwardswing. Many coaches also believe that a curved approach in soccer or kicking for goal in rugby enable the player to make better contact (a higher effective mass) with the ball.

3. THE USE OF COORDINATED MOVEMENTS

In sports where a high velocity of an implement is required, a number of body segments must be coordinated in such a way that a high velocity is achieved at impact or release. The motion of segments in high velocity striking and throwing skills are generally sequenced in a proximal-to-distal fashion. One of the most popular principles underlying the description of this sequencing in sport movements is the summation of velocity principle. This principle suggests that the velocity of the distal end of the linked system is built up by summing the individual velocities of all segments participating in the sequence, although the principle does not provide a mechanical explanation of how this is achieved: Putnam (1992) presented the view that joint angular velocity data provide a clear description of proximal-to-distal sequencing. Furthermore, these data enable coaches to visualize a movement as motion is generally characterised as a series of segment rotations. Other researchers such as Van Gheluwe and Hebbelinck (1985) have proposed an optimal coordination principle where to achieve maximum speed at the distal end of an open-linked system, the angular velocities of all segments should reach a maximum value simultaneously. While this sequence has been observed in some striking activities, most striking and throwing actions follow the summation of velocity principle (Putnam, 1992).

Practical Implications for Coaches: In sport, the use of a number of body segments, added together in a coordinated manner plays a part in velocity generation in a number of different ways.

* The first example would be in situations where forward movement of the body is added to the rotation of a body segment or number of segments. In fast bowling in cricket the velocity of the body developed during the run-up is added to the velocity developed by trunk and upper limb rotation to produce the release velocity of the ball. In kicking skills the velocity developed in the forward movement of the body is added to the velocity developed from trunk and lower limb rotations to produce an optimal foot velocity at impact.
* Another example would be where a forward step increases the distance over which velocity can be developed. That is, in baseball or hockey the player steps into the ball to enable a higher velocity to be developed. It is often preferable as a coach to visualise this as adding another segment to the movement to increase the potential to develop velocity.
* Players often attempt to generate higher velocities by adding more segments in the movement. In a basketball jump shot the velocity of the ball which may be developed primarily from elbow extension with beginners may later be taught with elbow extension and wrist flexion to develop a higher release velocity and thus enable the player to shoot further from the basket.

Movement patterns that require the coordinated action of total body movements are usually the sign of a mature action. The sequence of body segment movements for an overhand throw for distance would be as follows:

* Forward step and trunk rotation
* Horizontal flexion of the upper arm at the shoulder joint
* Extension of the forearm at the elbow joint
* Hand flexion at the wrist then occurs to complete the forwardswing to release.

The removal of any of these movements from the respective actions will have the effect of reducing the velocity capable of being generated.

4. THE ROLE OF MUSCLE STRENGTH AND ENDURANCE .

The relationship between selected physical capacities such as muscle strength and performance is relatively easy to assess in sports such as weightlifting, however, such a relationship is very difficult to quantify for the majority of sporting movements. How much strength is need to: pitch with a high velocity; kick a ball for distance or hit a powerful drive in baseball. Certainly no significant relationship has been found between muscle strength and serving velocity in tennis (Ellenbecker, 1989) or between muscle strength and kicking velocity in soccer (McClean and Jamieson, 1991).

Practical **Implications for** Coaches: The absence of research data that provide a definite amount of strength required for most sporting activities should not stop coaches from ensuring that their young athletes, who aspire to high levels of performance, include weight training as part of their training programme. Players must obviously develop sufficient muscle strength to perform effectively in a long match or over a large number of efforts. An increase in muscle strength, means that a less percentage of total strength, is needed for each movement, which may assist in the ability to repeat the performance with "good technique" over the entire match or competition. While the coaching emphasis pre-puberty in the majority of sports should be on skill training (women's gymnastics and swimming are examples of exceptions where muscle strength training must occur prior to puberty) as the greatest gains in muscle strength and endurance are achieved after puberty. (Malina, 1978).

5. THE ROLE OF EQUIPMENT DESIGN

While it is beyond the scope of this paper to fully discuss the implications of equipment design on all sporting movements, some mention of the relationship between equipment and performance in tennis shows how equipment design can play a role in developing an increase in ball velocity. In tennis a great deal of technological effort has been directed at racquet development in an endeavour to increase "power" and "control" while reducing the unpleasant vibrations produced by off-centre impacts. "Today the new breed of thicker, stiffer and more powerful rackets have gained immediate favour with the masses, and in the last year and half have taken over the market" (Sparrow, 1989, p. 47). String tension has also been shown to be a factor that influences post-impact velocity of the ball (Elliott 1982).

CONCLUSION

Increases in muscle strength, selection of the appropriate equipment to match a players style and the use of elastic energy to assist in body movement will all enable athletes to generate higher segment velocities. Good technique however, will always be the cornerstone needed for stroking or throwing with control. Biomechanical factors must therefore be taken into account when coaches decide what technique best suits the flair and body type of each of their players.

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