UPPER BODY MOVEMENTS IN ELITE JAVELIN THROWS

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INTRODUCTION

For a male javelin thrower to attain an Olympic medal it is likely that he will need to release the implement at a speed of approximately 30 $m.s^{-1}$ (108 $km.h^{-1}$). This will require the athlete to have a very high level of explosive power. Javelin throwers use a variety of weighted throwing exercises to develop the 'specific' power that is necessary to generate such high javelin release speeds. Central to the use of these exercises is the specificity principle of training which states that, "the induced change is specific to the exercise stress," (Enoka, 1994). Thus, overhead throwing training exercises should enhance the athlete's ability to throw for distance because they replicate the stresses that are placed upon the body during competition. This, of course, is based upon the assumption that an athlete will move in a similar way during training and competition. If this not the case, the usefulness of the training method is questionable. Coaches provide athletes with a set of training and throwing guidelines to ensure that the movements performed during each are a close match. For example, Paish (1976) suggests that during the throwing action the elbow must come through high and close to the vertical plane of the body. Furthermore this is thought to be essential from both a point of view of throwing distance (Paish, 1976) and injury prevention (Bowerman and Freeman, 1991). These authors seem to prefer a throwing action performed with the humerus extending rather than horizontal flexing.

Because athletes also follow specified guidelines when training, these exercises should replicate the thrower's actions when competing. Thus, in designing appropriate training exercises, and guidelines for the techniques involved in these exercises, it is necessary to accurately describe the thrower's movements when competing. Without this knowledge it becomes very difficult to prescribe relevant and correct training methods. The purpose of this study was to define the upper body movements of a group of elite javelin throwers during the delivery phases of world class competitive throws. This was conducted to identify the body segment movements which appear to make the major contribution to the release speed of the javelin.

METHODS

All throws of the twelve athletes competing in the 1995 World Athletics Championships men's javelin final were filmed. Each athlete's best throw, for which film was available, was then analysed. Filming involved two stationary phase-locked Photosonics 1PL cine cameras operating at 200 Hz that were situated with their optical axes at approximately 90° apart. The zoom lenses were prepared such that the athlete's movements, incorporating the last cross-over stride, the delivery and the first few metres of the javelin's flight after release, were in full view. Event synchronisation was achieved by a manual switch which was activated during the throw after the cameras had reached full speed. This resulted in a pulse being recorded on the opposite edge of the film from the timing marks. Prior to the competition a volume encompassing the last six metres of the 4 m wide javelin runway, to a height of 3.3 m, was calibrated using a system of poles. Attached to both ends of each pole were large reflective spherical markers which served as control points for the calibration system. The coordinates of each point relative to an origin marker were calculated using an Elta III tachymeter.

Digitisation of the throws and calibration system were conducted using a TDS HR48 digitising tablet which was interfaced to an Acorn Archimedes 440 microcomputer, running software reported by Bartlett (1990). The 3-dimensional object-space coordinates of eighteen points, defining a fourteen segment performer model, plus the tip, grip and tail of the javelin were then reconstructed from the two sets of image coordinates using a DLT algorithm, correcting for linear lens distortion. After computation of the thrower's mass centre coordinates and body angles required for biomechanical analysis, the data were smoothed and velocities and accelerations were calculated using cross-validated quintic splines.

RESULTS

Once the run-up is completed the effectiveness of the delivery will determine the distance of the throw. To make the delivery as effective as possible athletes accelerate the larger body segments first so that smaller parts, such as the wrist and hand, have momentum at the end of the movement. Table 1 shows the peak linear speeds of the most important upper body joints relative to the body centre of mass. This gives an indication of the ability of the athlete to utilise the power of the upper body to accelerate the javelin.

		Linear speed of joint centres of throwing arm/m.s^{-1}		
Thrower	Dist./m	Shoulder	Elbow	Wrist
1 st	89.06	7.7	12.2	20.9
2 nd	86.30	6.5	13.1	20.8
3 rd	86.08	7.2	11.1	18.8
8 th	79.72	6.3	12.4	20.2
7 th	79.54	5.9	11.4	17.5
6 th	79.06	6.7	11.2	18.1

Table 1. Linear speeds of the throwing arm joints for the six analysed throws.

Inspection of table 1 shows that the major differences in techniques between throwers occur in the more distal segments. For instance, the peak right shoulder joint linear speeds vary within a range of 1.8 m.s^{-1}. For the right elbow and wrist joints this range increases to 2.0 m.s^{-1} and 3.4 m.s^{-1} respectively. It would seem to be in the latter stages of the delivery that the biggest distinction in the techniques of these throwers are evident. This is not surprising when one considers that over 60% of the javelin release speed generated by the gold medallist was achieved in the 60 ms immediately before release. During this very short period, lateral trunk rotation continues but at an ever decreasing rate as does the rate of shoulder extension and horizontal flexion. The major movements that are occurring, or are still to occur, are medial rotation of the shoulder, elbow extension and wrist and finger flexion. In which case, it would appear that not only must the javelin thrower create very large muscle forces to produce such fast body segment movements, but that the acceleration of these segments must follow a very coordinated pattern. Otherwise the finer movements of the most distal segments will not contribute greatly to the acceleration of the javelin, when for elite athletes such as these, they appear to be very important indeed.

	Angular velocity of body segment/rad.s^{-1}			
Thrower	Hip/Shoul	Hum_Tru	Elbow	Hum Med Rot
1 st	22.8	18.6	56.3	39.6
2 nd	14.2	23.2	45.2	22.7
3 rd	20.9	14.4	46.5	18.8
8 th	12.2	14.4	43.7	22.1
7 th	11.7	20.4	31.1	20.4
6 th	22.4	19.4	36.2	19.2

Table 2. Peak angular velocities between the hip and shoulder axes (Hip/Shoul), the three-dimensional angle between the humerus and the trunk (Hum_Tru), the right elbow angle, and the average angular velocity of the humerus in medial rotation between the instants of maximal external rotation and javelin release (Hum Med Rot).

Table 2 gives an indication of the different upper body movements which will produce the linear speeds of the joint centres listed in table 1. The first column shows the peak horizontal angular velocity between the hip and shoulder axes in the delivery movement of each thrower. It would appear that for the gold medallist and the sixth placed athlete, rotation of the trunk was very important as peak angular velocities were in excess of 22 rad.s^{-1}. The second column shows the peak angular velocity for the three-dimensional angle made by the right humerus and the trunk. The highest value can be seen for the silver medallist who attained a value of 23.2 rad.s^{-1}. This movement was primarily shoulder joint extension combined with some horizontal flexion, and seemed to be very important in the delivery for this thrower. Column three represents the peak angular velocity of the elbow joint. It can be seen that the gold medallist relied relatively heavily on this movement to accelerate the javelin. A value of 56.3 rad.s^{-1} was achieved by this athlete. Column four shows the average angular velocity for medial rotation of the humerus between the instants of maximum lateral rotation and javelin release. This value has been highlighted as being particularly important in other overhand throwing activities such as baseball pitching (e.g. Atwater, 1979), but is rarely reported in javelin throwing. Once again the gold medallist was able to generate the largest value of medial rotation (39.6 rad.s^{-1}) but this movement would appear to be important in the techniques of all six athletes.

Probably the major contrast in throwing style was achieved between the gold and silver medallists. It is interesting to compare the delivery movements of these athletes as they both achieved the same javelin release speed of 30.1 m.s^{-1}. The gold medallist is seen to rely on lateral rotation of the trunk and strong humerus medial rotation with extension of the elbow joint. Whereas, the silver medallist seemed to rely more on extension of the shoulder joint coupled with a moderate degree of medial rotation and extension of the elbow joint. Such differing styles between these two athletes would mean that the training that each performs needs to cater for their particularly different delivery movements. This does not mean that training exercises such as overhead medicine ball throws are more beneficial to one athlete rather than another. However, the gold medallist performing such exercises using the guidelines suggested by Paish (1976) and Bowerman and Freeman (1991) would gain little benefit, because this athlete relies more heavily on movements not addressed in such guidelines.

CONCLUSIONS

It is evident that javelin throwers of the highest level have very different movement patterns which allow them to release the implement at speeds in excess of 30 m.s^{-1}. These differences are particularly evident in the latter stages of the throw (last 60 ms) when over 50% of the javelin's release speed may be developed. Because of these differences it is essential that an athlete's throwing technique is fully understood before training exercises, and the guidelines for the execution of these exercises, are prescribed. Otherwise, the effect of such training exercises may be irrelevant or even detrimental to the athlete's throwing performance.

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