EFFECT OF HIP-SHOULDER AND SHOULDER-ARM SEPARATIONS ON DISCUS THROWING PERFORMANCE

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The purpose of this study was to analyze performances of nationally competitive discus throwers to ascertain which launch phase technique variables have the most influence on release characteristics and official distance. Three-dimensional videography was used to analyze 259 trials. The angles in the horizontal plane between the line of the athlete's hips, shoulders, and throwing arm, at six critical instants of the launch phase were calculated and analyzed. Our data suggests females utilize effective body positions throughout more of the launch phase to maximize the distance thrown. In contrast, males rely mainly on their upper extremity strength to achieve comparable results.

KEY WORDS: discus, biomechanics, technique analysis

INTRODUCTION: The performance outcome of interest for discus performance is the legal official distance thrown the competitor with the longest throw wins. Any technique that can maximize that distance gives an athlete the best chance of winning. The throw can be partitioned into two phases: the launch phase and the flight phase (Hubbard 1989). The launch phase consists of all of the thrower's actions inside the circle with the discus in hand. This study is concerned with how inter-athlete technique variations during the launch phase affect the distance thrown. We will analyze trials at easily identifiable pre-determined critical events, dependent on foot contact. The critical events are defined as follows: 1) maximum backswing, 2) right foot off, 3) left foot off, 4) right foot touchdown, 5) left foot touchdown, and, 6) release. This is consistent with divisions used in previous research (Bartlett 1990b & Susanka, *et al.* 1988), so allows for comparisons to be made. Any correlations between technique variables - hip-shoulder leading angles (HSA), and shoulder-arm leading angles (SAA) at critical instants - and distance thrown will be reported. These correlations will allow for comparisons to be made between our database and values reported in prior studies (Burke (1988), Johnson (1985), Lindsay (1991) and Susanka, *et al.* (1988) for example). Suggestions will be made about attaining effective body positions for maximizing distance.

METHODS: Two hundred and fifty nine competitive throws of male and female discus throwers were collected during eleven outdoor track and field meets. Two Panasonic PV-GS15 digital camcorders were used to record every throw, as well as a 24-point calibration frame at each competition. One camera was positioned behind the circle facing the approximate direction of throw, with the other to the right hand side of the circle so direction of travel was from left to right. Both video clips for each throw of interest were manually digitized using Peak Motus 6.1. Twenty-one body landmarks and joint centers, as well as the discus centre, from just prior to maximum backswing, until the discus left the field of view, were digitized. Best estimates were used for frames where limbs were obscured from view. The calibration frame specific to each meet was also digitized. These 2-D coordinate data were then synchronized using the direct linear transformation method and smoothed with a Butterworth filter at a cut-off frequency of 7.14 Hz in MSDLT, to obtain 3-D coordinate data. DiscAnz 2.0 was used to calculate the technique variables and release characteristics from the 3-D coordinates for every trial. Discus release velocities and angle of release were obtained mathematically from locations of the discus at the instant of release and ensuing frames. The hip-shoulder and shoulder-arm separations were calculated as angles between imaginary lines joining the digitized hip joint centers, shoulder joint centers, and a line running from the shoulder joint center to the centre of the discus, which assumed the arm to be straight at each critical instant.
A positive HSA was defined as the line of the hips leading the line of the shoulders (Figure 1). A positive SAA was defined as the line of the shoulders leading the arm (Figure 1). Reduced

data were collated, grouped by gender and four official distance groups (ODGs) & analyzed (Table 1). SPSS 11 was used for all statistical analyses.

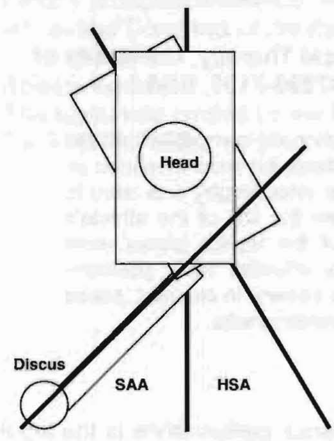


Figure 1 Technique Variables.

Table 1 No. of Trials Collated by ODG and Gender.

Official Distance Group		Female	Male
1	(Below 55 m)	44	12
2	(55 m – 60 m)	55	45
3	(60 m – 65 m)	37	49
4	(Over 65 m)	4	13

RESULTS: The best female throwers show larger separations between the line of the hips and the throwing arm at maximum backswing. Fifteen degrees greater than the lowest ODG. This was achieved with a larger HSA. Male throwers display more consistent angles of approximately 128°. Elite throwers tend to release the discus at larger magnitude release velocities. Speed at release increased by 1.4 ms^{-1} for women and 2.4 ms^{-1} for men from ODG-1 to ODG-4. Elite females tended to release the discus at a steeper release angle.

For female throwers, HSA-5 ($r = 0.221$, $p < 0.01$), SAA-3 ($r = 0.227$, $p < 0.01$), SAA-4 ($r=0.225$, $p < 0.01$), & SAA-5 ($r = 0.337$, $p<0.01$) have increasing trends with ODG (Figure 2 - Figure 5). For male throwers, HSA-3 ($r = -0.323$, $p < 0.01$) has a decreasing trend with ODG. The release characteristics of vertical discus release velocity ($r = 0.363$, $p < 0.01$, female; $r=0.288$, $p < 0.01$, male) and resultant release speed ($r = 0.402$, $p < 0.01$, female; $r = 0.431$, $p < 0.01$, male) for both male and female throwers, as well as angle of release ($r = 0.183$, $p<0.05$), for female throwers only, were all positively related to ODG. An increase in any of these release characteristics resulted in an increase in distance thrown.

Fig 2 - Mean Separation Angle (degrees) Between Hip and Shoulder at Left Foot Touchdown

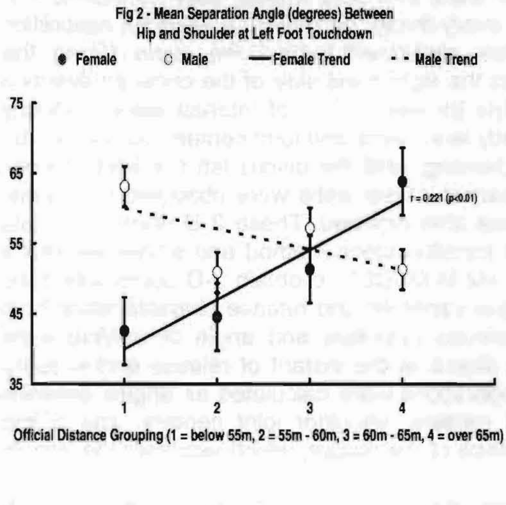


Fig 3 - Mean Separation Angle (degrees) Between Shoulder and Arm at Left Foot Takeoff

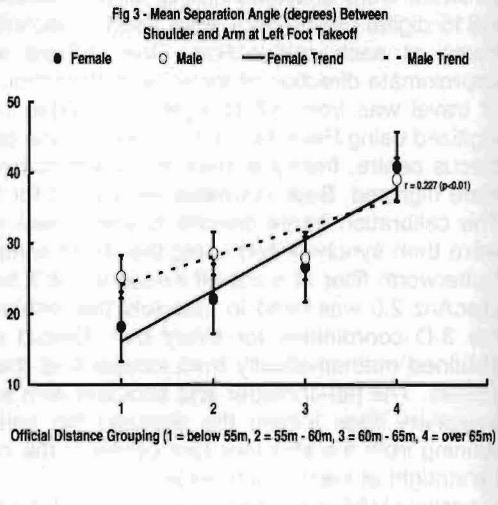


Fig 4 - Mean Separation Angle (degrees) Between Shoulder and Arm at Right Foot Touchdown

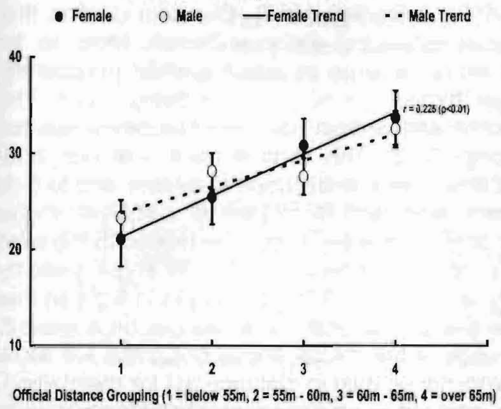
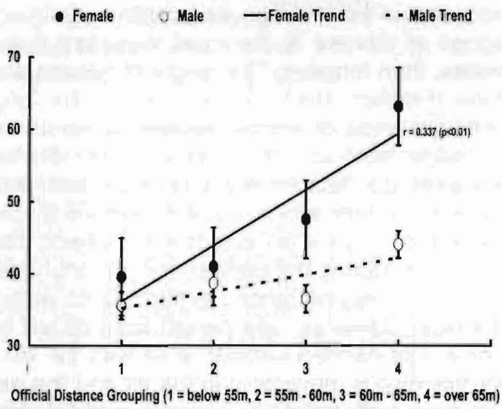


Fig 5 - Mean Separation Angle (degrees) Between Shoulder and Arm at Left Foot Touchdown



DISCUSSION: From the larger number of technique variables which correlated with ODG, it can be inferred that elite female discus throwers are reliant on technique to achieve their long throws. Conversely, male discus throwers did not show as many significant relationships between technical measures and performance, which indicates a large within ODG variation in technique, and an increased dependence on strength to throw further.

The distance the discus travels once it has left the hand is proportional to the horizontal speed it has at release, multiplied by the time for which it is airborne. Horizontal speed at release is dependant on the force applied to the discus by the athlete, as they accelerate it throughout the entire throwing procedure. Increasing either the magnitude of the force, or the length of time for which it is applied will result in a higher release speed. The force applied to the discus is related to the strength of the thrower. The time for which the force is applied depends on the path of the discus, particularly from maximum backswing to right foot off (first double support phase), and from left foot down to release (delivery phase). Up to 25% of the horizontal speed of the discus is obtained during the first double support phase and 62-73% during the delivery phase (reported in Bartlett 1992). A discus that travels along a greater path will have forces applied to it for a longer time. The path traveled by the discus in the horizontal plane during the entire throwing procedure depends on the hip-shoulder and shoulder-arm separations. An athlete with large positive HSA and SAA at maximum backswing and left foot down, that subsequently decrease at right foot down and release, respectively, will have moved the discus along a greater path than if the limb segments were parallel or separated less throughout the launch phase. The hope is that the path is large enough to accelerate the discus maximally. Therefore, if an athlete has these separations at the specified critical instants, they will maximize the path distance, the time for which forces are applied, the speed of release and official distance. From our data, it can be seen that female discus throwers, particularly elite females, utilize this technique much more effectively than males. Elite female discus throwers have more separation between the line of the hips and the line of the throwing arm at maximum backswing than any other group. The women display significantly large HSA at left foot down (Figure 2), which decreases throughout delivery up to release, where it approaches 0^{o}. They also show significantly large SAA from left foot off until release, where again it approaches 0^{o}. The male discus throwers do not (Figure 3-5). Large separations between limb segments are also important to stretch the trunk rotators dynamically. This allows for energy to be stored in the elastic, non-contractile element of these muscles, which can then be released during the delivery, and supplement the force applied by the contractile muscle element. In this way, an increase in the force applied can be achieved through effective technique, not just resistance training.

The flight of the discus after release can be only minimally influenced by the thrower, because the two are no longer in contact. Factors athletes do influence include the speed of release, height of release, and the angle the discus makes with a global reference frame.

Several studies have quantitatively assessed the effect of these release characteristics on distance thrown. They found that release speed is the most important release characteristic and should be as large as possible (Knicker 1990 & Bartlett 1992). Our data confirm that speed of release is the most important factor in optimizing distance thrown. More so for males, than females. The height of release should be as large as possible whilst maintaining form (Frohlich 1981), since it allows for longer throws, all other things being equal. The optimum angle of release relative to the horizontal and vertical velocities has been reported to range from 35°-37° (Frohlich 1981 & Soong 1976). This is consistent with our data; however, our data show this to be of much less importance than speed of release and to only have significant effects for elite female throwers, who tend to release at a steeper angle. Since the discus is an aerodynamic object, this angle of release should be related to the wind conditions during the competition; unfortunately, none were recorded. The tilt angle made by the discus also influences its flight as an aerodynamic object. If the discus tilts in flight so that it travels sideways, any benefit from lift will be lost and shorter distances will be achieved. For a right-handed thrower, a tilt with the left edge of the discus above horizontal will allow for this discus movement in the air and the aerodynamic gain in distance will be maintained. We have further data to suggest aerodynamic distance is an important consideration, more so for female discus throwers than males. The optimum HSA and SAA at release is reported to be 0° (Susanka, et al. 1988, Knicker 1990 & Lindsay 1991), i.e. parallel, which releases the discus tangentially. From our data, it can be seen that elite women release much closer to parallel. Male and non-elite female throwers release the discus when their throwing arm has traveled past parallel. Both a sign of flawed technique (Knicker 1990 & Lindsay 1991) and a reliance on arm strength. Releasing past parallel also makes it harder for athletes to control the tilt angle.

CONCLUSION: In summary, it can be seen that elite female discus throwers utilize significantly larger limb separations than male and non-elite female throwers during the phases where most release speed is generated. They do so to increase both the force applied to the discus, as well as the time for which it is applied. Elite female throwers also display optimal release characteristics to maximize distances. It is suggested that male and non-elite female throwers focus on honing their techniques to achieve similar optimal body positions throughout the entire throwing procedure.

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