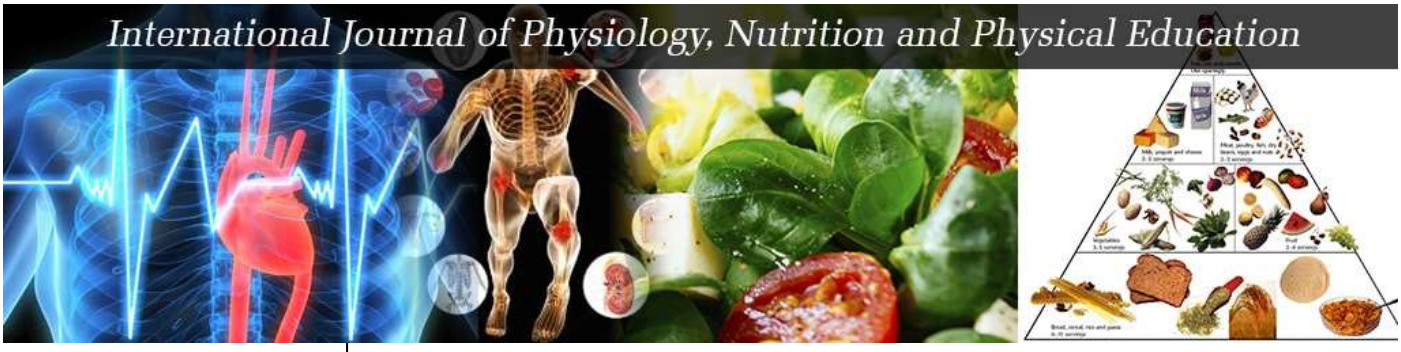

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Dr. Manesh Kumar Murali M
Post-Doctoral Fellow, Department of Physical Education, University of Calicut, Calicut University (P.O), Malappuram, Kerala, India

Dr. Sakeer Hussain VP
Director, Department of Physical Education, University of Calicut, Calicut University (P.O), Malappuram, Kerala, India

Corresponding Author:
Dr. Manesh Kumar Murali M
Post-Doctoral Fellow, Department of Physical Education, University of Calicut, Calicut University (P.O), Malappuram, Kerala, India

The influence of selected kinematic parameters on discus throwing performance

Dr. Manesh Kumar Murali M and Dr. Sakeer Hussain VP

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Abstract
The purposes of this study were to investigate the effect of the selected kinematical parameters and official distance. Video graphic data of best 13 male discus throwers' competitive performances were captured during in 55th National Inter State senior Athletics Championships - 2015, held at Jawaharlal Nahru Stadium, Chennai. Eight variables were selected for the study. They included Official Distance (m), Release Angle (deg) Release Height (m), Release Velocity (m\s), Shoulder-hip separation at release (deg), Arm- shoulder separation at release (deg), Throwing arm elevation at release (deg), Trunk forward-backward tilt at release (deg). Basic parameters were extracted by customary kinematic analysis method using the three-dimensional DLT was applied to locate three-dimensional coordinate data of the endpoint of 15 body segments with one part of discus. The release velocity, height and angle are presented as important biomechanical parameters. Suggestions for controlling the height of release and the release velocity of the using an effective technique for improved performance. Additionally, release velocity must be improved because throwing distance is directly proportional to squared release velocity. In conclusion, the current study demonstrated comprehensive kinematical analyses, which can be used to instruct the jumping discus throwing technique with duration and angle characteristics of throwing movement for athletes by coaches with videos.

Keywords: Release velocity, release height, throwing arm elevation

Introduction
Discus throw is a highly technical track and field event. Discus throwing is one of the four throwing events in track and field. Complicated movements performed at high speed in a limited space make the discus throw technically and physically demanding. The technique of the discus throwing consists of the preliminary swings, the preparation, the entry, the airborne, the transition, the delivery and the recovery (Bartlett, 1992) [4]. Under the perspective of leg support, the discus technique is structured as the double and single support starting phases, the support less phase, and the single and double support delivery phases. Thus the discus throw requires thorough biomechanical analysis to have a good understanding of technique and training of elite discus thrower.
In the discus throw release velocity, height and angle are commonly presented as the most important biomechanical parameters at studies conducted in major track and field competitions (Ariel *et al*., 1997; Bandura, 2010; Bartonietz *et al*., 1996; Gregor *et al*., 1985; Knicker, 1992; Knicker, 1994a; Knicker, 1999; Miyanishi *et al*., 1998) [1, 3, 5, 13, 18, 17, 16, 22] Each athlete, taking into account their individual differences, both in their body structure and in the execution of sports gestures, has variability in their patterns and their relationship with those of other athletes. Thus, researching the variability of movement in an intra- and inter-individual way is a new approach to the evaluation, diagnosis and control of sports techniques (Ramon, 2009; González-Catalá & Calero-Morales, 2017; Criollo Romero, Espinoza Saltos, Calero Morales, Chávez Cevallos, & Fleitas Díaz, 2018) [23, 14, 9].

Materials and Methods
The thirteen participants were taken for the study (age: 18 to 40±4 years, body height: 1.94±0.09 m, body mass: 119.4±11.6 kg).

All the subjects were men done their discus throw event in 55th National Inter State senior Athletics Championships - 2015, held at Jawaharlal Nahru Stadium, Chennai. All participants were right handed and all attempts were recorded. All attempts expect the foul was suitable for the study. The selection of the competition was based on the fact that the top ranked athletes of the entire competitive season were permitted to participate.

Data acquisition

All trial throws of the participants were recorded from the right side and back side of the athletes during the examined competitions. The recordings were acquired with two stationary DV Came Pd - 170 digital video camera (Sony Company Japan Ltd), the three-dimensional DLT method was applied to locate three-dimensional coordinate data of the endpoints of 15 body segments with one part of discus. The local coordinate system was expressed with a right-handed orthogonal: the z-axis was vertical and pointed in the upward direction, the y axis was horizontal and pointed in the throwing direction, and the x-axis was perpendicular to the other two axes. The coordinate data were smoothed with a Butterworth digital filter at optimal cut-off frequencies (3.0 - 10.8Hz), determined from the residual analysis proposed by Winter (1990) [27].

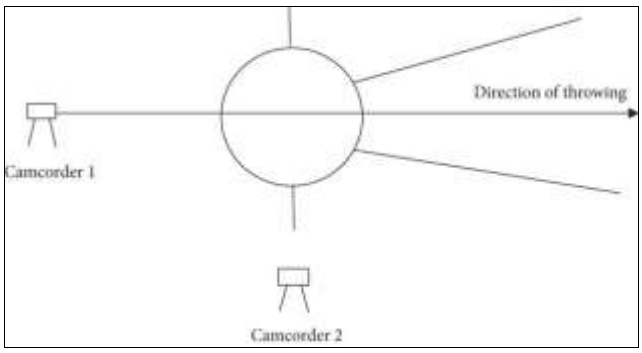


Fig 1: 3D kinematic shooting diagram

Kinematic Parameters

Eight variables were selected for the study. They included Official Distance (m), Release Angle(deg) Release Height(m), Release Velocity(m\s), Shoulder-hip separation at release (deg), Arm- shoulder separation at release (deg), Throwing arm elevation at release (deg), Trunk forward-backward tilt at release (deg).

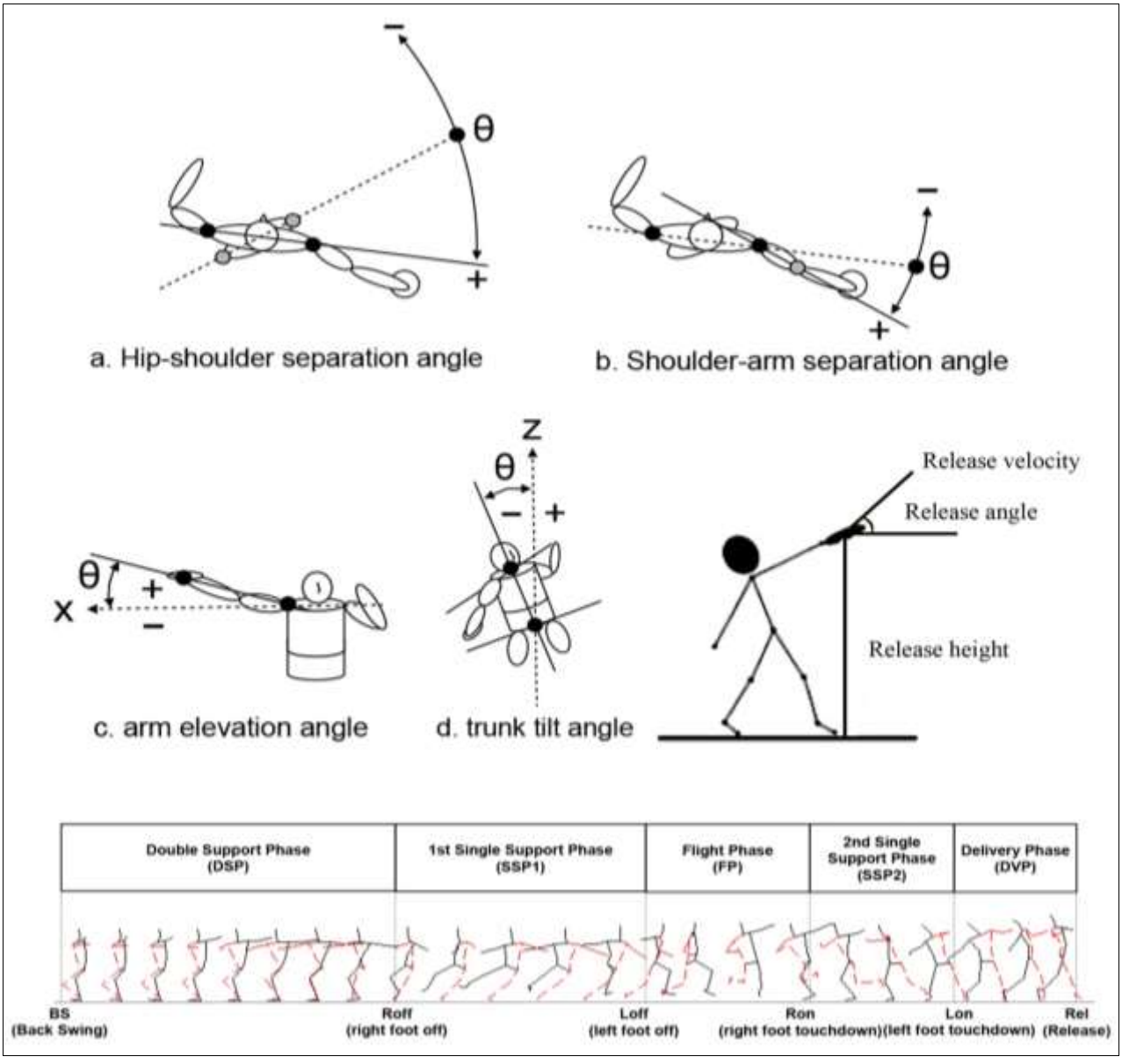


Fig 2: Operational Terminology and variables selected for the study

Software used for the study

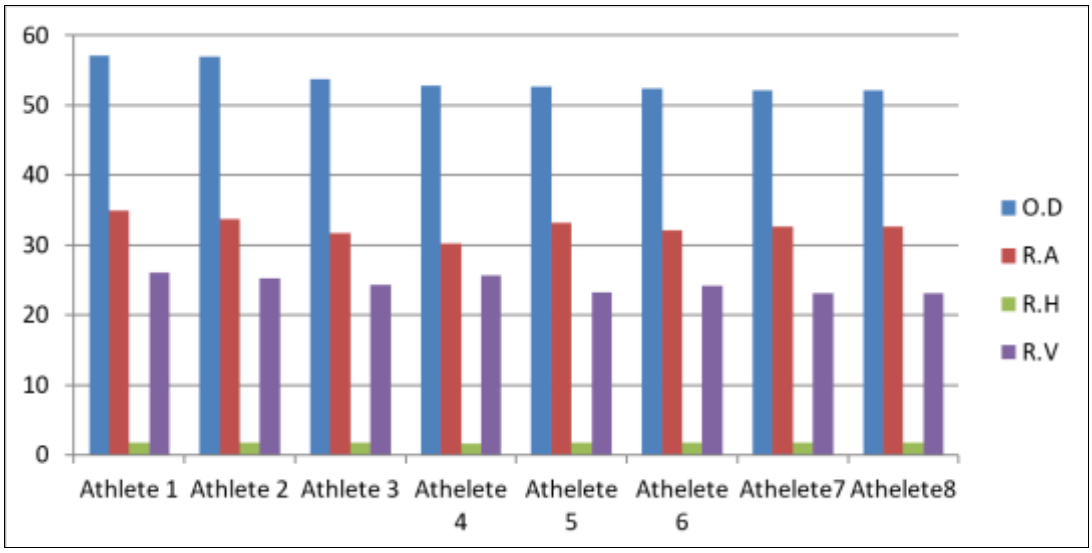
The values of the variables were obtained using the software for Quintic biomechanics 26, Quintic Consultancy Ltd.

Results: In the 55th National Inter State senior Athletics Championships - 2015, held at Jawaharlal Nahru Stadium, Chennai, the best discus throws ranged from 57.14 m to 39.64 m and the medals were decided by throws over 57.14 m

Table 1: Correlation with Official distance

Variables	SD	Correlation
Release Angle	1.82	-0.3 ns
Release Height	0.062	0.32*
Release Velocity	0.083	0.05*
Shoulder-hip separation at release (deg)	1.06	-0.46 ns
Arm- shoulder separation at release (deg)	0.72	-0.56 ns
Throwing arm elevation at release (deg)	0.909	0.55*
Trunk forward-backward tilt at release (deg)	0.783	-0.44 ns

* Significant at 0.05 level, Non-significant at 0.05 level



Graph 1: Comparison of Official distance with release angle, Release height and Release velocity among 8 finalist athletes under the study.

Release height was found to be significant at 0.05 level r = 0.32, (p>0.05) with that of the throwing distance. Significant correlation was found between release height (r = 0.32 p>0.05) and release velocity (r = 0.05 p>0.05) with that of official throwing distance. In all the case, the correlation was found to be positive which indicates that as the release velocity and release height increases javelin delivery distance increases. So that is an indication of perfect relationship between release velocity and official throwing distance. As the release velocity increases there is a positive increase of delivery distance. In the case of Points are around a straight-line and not on the line which is an indication of moderate level of relationship between release height and official throwing distance. Throwing arm elevation angle @ Instant of release (deg) found to be Significant (r = 0.55 p>0.05). All the other variable among the athletes shows no significant relationship with that official throwing distance.

Discussion

Discus throwers' performance is mainly determined by their throwing distance, which can be affected by release height, velocity, and angle (Chen *et al* 2019) [8], and the result of the current study showed that the release velocity had high positive correlation with the throw distance. On average, world-leading male discus throwers can achieve a throwing distance of 64.17-66.76 m, release velocity of 23.88-25.71 m/s, release angle of 32.02°-37.23° (Bennett *et al* 2017) [7], and release height of 1.4-2.0 m (Leigh *et al*., 2008) [20]. It was confirmed that release velocity was the single most important factor for Official distance since a strong correlation was revealed as previously noted (Bartlett & Best, 1988; Bartonietz, 2000; Lehmann, 2010; Mero *et al*., 1994; Viitasalo *et al*., 2003) [6, 15, 11, 2, 26]. The results of this study suggestthat no single kinematic parameter taken in isolation (e.g release velocity) can predict the distance thrown. Distance probably results more from a complex interaction between several different parameters, as well as the unknown wind factor. Some athlete's showed difference regarding attack, release and attitude angles, but differed on release velocity and release height, due in part to body size and strength. Nevertheless, the linear statistical regression indicates that only release speed made a significant contribution in predicting the range of the discus throw (Teraudus 1978; Gregor *et al*. 1985; McCoy *et al*. 1985; Yu *et al*. 2002; Dinu *et al*. 2004) [25, 13, 21, 28, 10].

The release height is the distance between discus centre of mass (CM) and the ground at the moment of release. Increase in the height of release keeps the discus in air for a longer time, resulting in increase of the range (Soong 1976) [24]. An increase of 1 m in release height would increase the range to about 2 m (Frohlich 1981) [12], but elite discus throwers maintain variations of few degrees in competitions (Knicker 1997) [19].

The throwing arm elevation angle (γ) was defined as the projection angle of the right shoulder-discus vector to the X axis of the shoulder's local coordinate system on the XZ plane, with a positive value indicating that the discus was in a position higher than the right shoulder (i.e., the right shoulder

was raised) and a negative value indicating that the discus was in a position lower than the right shoulder (i.e., the right shoulder was depressed).

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