WHY OVER-ROTATION IS NOT GOOD FOR ROTATIONAL SHOT PUT?

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This study used three-dimensional motion analysis to determine the motion of rotational shot put. We sought to elucidate the effect of over-rotation in rotational shot put. The results showed that dirction of the center of gravity of the body (CG direction) correlates with the angular momentum of the shot-and-thrower system. As the magnitude of variability of CG direction relative to the horizontal plane increased, angular momentum of the shot-and-thrower system relative to its vertical axis decreased at the second turn ($p < 0.05$). CG direction showed a strong dependence on the contact position of the foot. We suggest that throwers avoid over-rotation by placing the foot straight from L-off to L-on.

KEY WORDS: shot put, rotation, angular momentum.

INTRODUCTION: The rotational shot put motion is divided into three main phases: turn, delivery, and reverse (Figure 1). Lukens (1989) showed that beginners do not pivot their left foot at the turn phase. Turk (1997) stated that one problem is often caused by over-rotation, which keeps the thrower from holding his posture at the turn phase. Turk (1997) also discribed that over-rotation is caused by pivoting of the left foot. These results suggest a relation between the lower leg motion and over-rotation. It also appears that throwers, especially beginners, find moving the lower leg at the turn phase difficult to understand. Thus, elucidation of the effect of over-rotation and the relation of over-rotation and lower leg motion will be beneficial for the beginners.
Therefore, we sought to elucidate the effect of over-rotation and suggest new techniques for avoidance of over-rotation.

METHODS: 7 male shot putters provided written informed consent to participate in the present study (age: 21.0 ± 1.8 years; height: 176.0 ± 5.6 cm; weight: 84.0 ± 23.3 kg; personal best: 12.99 ± 1.39 m), which was approved by the Ethics Review Committee of National Institute of Fitness and Sports in KANOYA. The throwing motion was assessed using a three-dimensional motion analysis system (MAC3D, Motion Analysis). The sampling frequency of the MAC3D cameras was set at 300 Hz and the experiments were performed

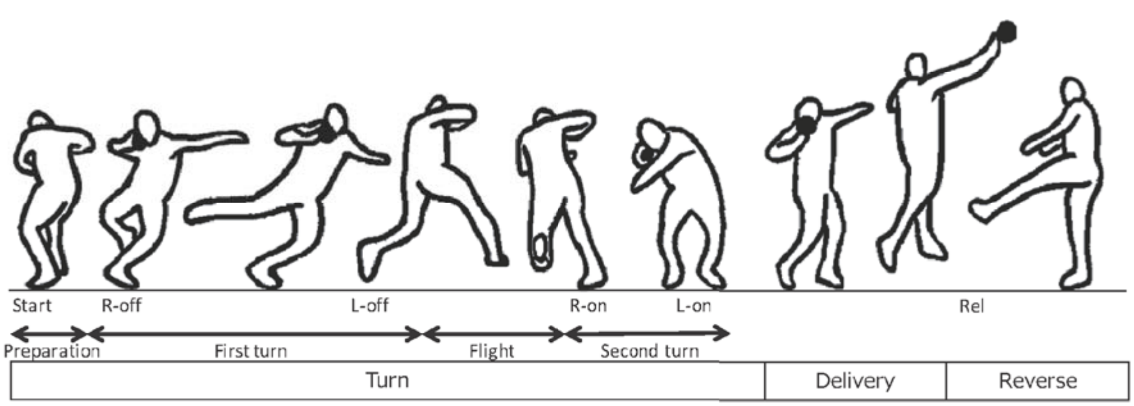

Figure1: Defined motion phases of rotational shot put

outdoors. Subjects threw the shot with maxmum effort as many times as they could. Thirty-six reflective markers for the body and two for the shot were measured; the obtained results were entered into the Cortex (Motion Analysis) software. A 30-Hz Butterworth digital filter was used to process the position data. For analysis and description of the data, the throwing motion was defined by the six phases shown in Figure 1. The phases of preparation, first turn, flight, second turn, delivery, and reverse were assigned based on the foot contact and release of the shot (Start; R-off: right foot take off; L-off: left foot take off; R-on: right foot contact; L-on: left foot contact; Rel: release of shot). The motion data were calculated using the following smoothed position data: displacement of center of gravity of the body (CG) in relation to the horizontal plane, CG direction; converting displacement of CG to straight line using least squares method and calculate the angle between the line and y-axis, angular momentum of the shot-and-thrower system in relation to its vertical axis, Contact position of the right foot; the angle between a vector from the left toe at L-off to the right toe at R-on and y-axis, contact position of the left foot; the angle between a vector from the right toe at R-on to the left toe at L-on and y-axis. The relationships among the various parameters were quantified using linear correlation techniques with the significance level for statistical analysis set at $p < 0.05$.

RESULTS and DISCUSSION: Figure 2 shows the relationship between the magnitude of variability of CG direction; the angle between CG direction before R-on and the second turn,

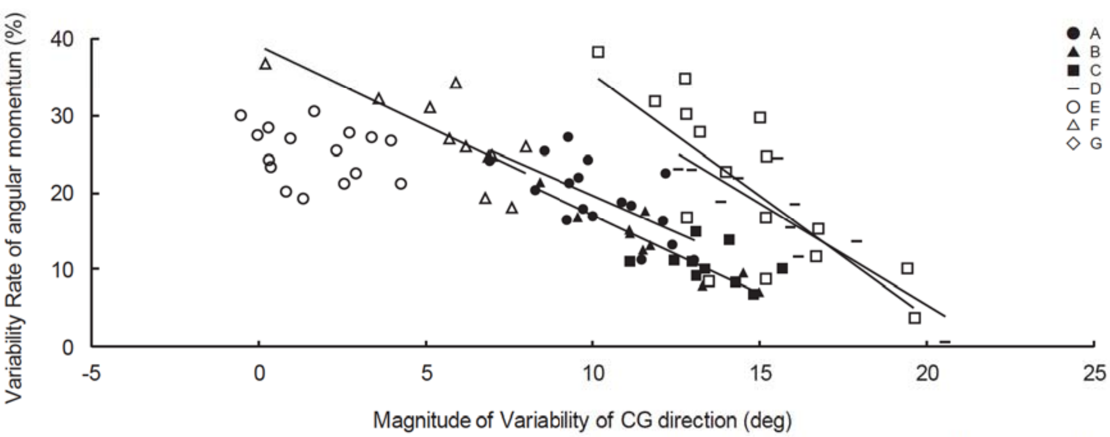

Figure 2: Relationship between the magnitude of variability of CG direction and the variability rate of angular momentum at the second turn.

Table 1: Number of trials and correlation coefficients between the magnitude of variability of CG direction and the variability rate of angular momentum at the second turn.

Subject	Number of trials	Correlation coefficients	P value
A	18	-0.580	<0.05
B	10	-0.921	<0.001
C	10	-0.323	0.32
D	10	-0.874	<0.01
E	16	-0.223	0.41
F	11	-0.771	<0.01
G	18	-0.757	<0.01

and the variability rate of the angular momentum at the second turn; the rate of angular momentum at L-on to R-on. Table 1 shows the number of trials for each sunjects and the correlation coefficients between these parameters. The magunitude of variability of CG direction is negatively correlated with the variability rate of the angular momentum for the subjects A, B, D, E, and G. While a significant correlation was not found for subject E, the magnitude of variability of CG direction was small in this case and the variability rate of the angular momentum was high. These results indicate that because of over-rotation, thrower will be not able to hold his posture and come left side of y-axis: center of throwing area, at a transition from the first turn to the second turn. Ohyama et al. (2008) have shown that the momentum gained or maintained during the second turn is the key factor for ensuring the energy source for the delivery. This result implies that over-rotation decreases the energy source for the delivery, and is therefore unfavorable for extending the throwing distance. Figure 3 shows the relationship between contact position of right foot and CG direction at the first turn and the flight. The right foot position is positively correlated with CG direction for all subjects ($r = 0.730$-0.970, $p < 0.05$, 0.01). Figure 4 shows the relationship between contact position of the left foot and CG direction at the second turn. The left foot position is positively correlated with CG direction for subjects B, C, D and F ($r=0.788$-0.997, $p<0.01$). These results suggest that over-rotation is determined by contact position of the feet as well as that the thrower can use CG direction to observe where the feet is contacted. Thus, the throwercan avoid over-rotation by contacting the feet in a straight fashion, leading to a line from L-off to L-on.

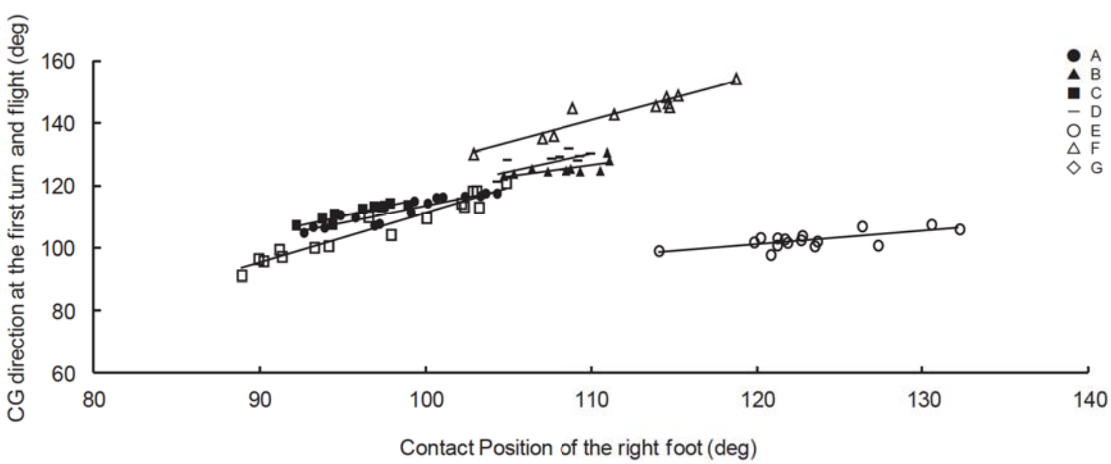

Figure 3: Relationship between contact positon of right foot L-off and CG direction att first turn and flight

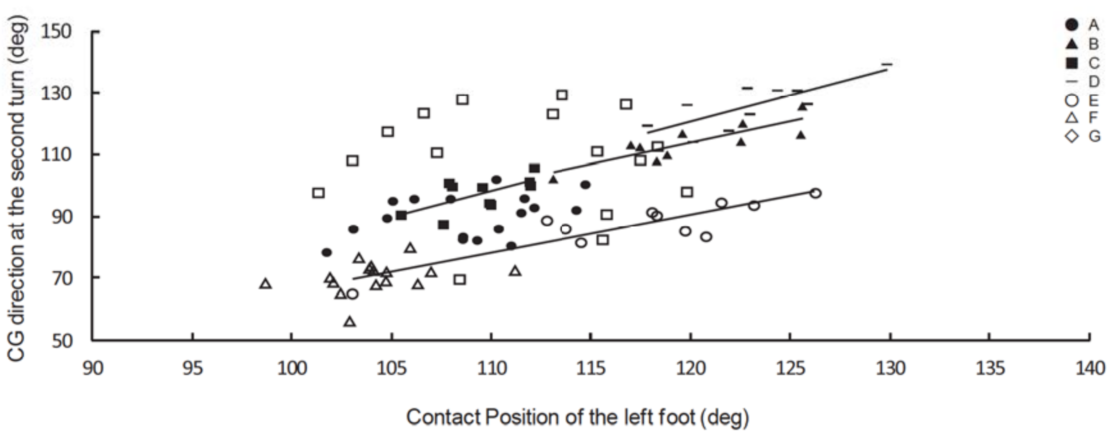

Figure 4: Relationship between Contact positon of left foot and CG direction at second turn

CONCLUSION: In this study, we investigated the effect of over-rotation. Over-rotation decreases the angular momentum at the second turn and is therefore unfavorable for achieving an extended throwing distance. The magnitude of variability of CG direction is closely related with over-rotation and depends on contact position of the feet. The thrower should contact with the feet placed straight to avoid over-rotation.

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