INTRODUCTION

Discus throwing is a physically and technically demanding sport. The goal is to achieve maximum discus release speed with optimal release heights and release angles. Previous studies have demonstrated that discus throwing performance was associated with selected technique variables [1].

Intra-individual variability may affect discus throwing performance. Previous studies assumed the movement patterns of skilled discus throwers were relatively invariant [1]. Research in other sports has shown less variability in skilled athletes compared to unskilled athletes, while some studies suggested a potential increase in functional variability in elite athletes [2]. The relationships between technique variability and performance during discus throwing have not been investigated.

The purpose of this study was to investigate the relationships between technique variability and performance during a discus throwing event. We hypothesized that athletes with better performances would have less variability (better consistency) in technique variables.

METHODS

18 male and 15 female discus throwers competing in the 2010 USA Outdoor Track & Field Championships were included in this study. Throwers’ three throws during the first round were recorded by two S-VHS video camcorders at a frame rate of 60 Hz.

The global reference markers, body landmarks, and the centre of the discus in each camcorders view were manually digitized [1]. The direct linear transformation procedure was used to obtain three-dimensional coordinates which were then filtered through a Butterworth low-pass filter at 7.14 Hz [1].

The critical instants of maximum backswing and release of the discus were identified for every trial. Considering the key techniques and the major joints contributions to discus delivery, eight joint angles were chosen. Arm-shoulder separation angle (ASS), arm-shoulder elevation angle (ASE), shoulder-hip separation (SHS), right hip flexion angle (RHF), left hip flexion angle (LHF), right knee flexion angle (RKF), left knee flexion angle (LKF), and trunk forward-backward tilt angle (TFBT) were calculated and normalized into 101 points from maximum back swing to release of discus [1]. For each angle, the standard deviation (SD) of three trials of each thrower was calculated at each point. The mean of SDs of all 101 points was calculated for each angle as variability measurements [3].

The best official distance for each thrower was used as the measurement for performance, because this determined their final place in the competition. Pearson correlation coefficients (PCC) between best official distance and mean SD of each angle were calculated with a Type I error rate set at 0.05. Males and females were analyzed separately.

RESULTS AND DISCUSSION

For males (Table 1), performance was significantly and negatively correlated with mean SDs of ASE, SHS, RHF, LHF, RKF, LKF, and TFBT. For females (Table 2), although most of PCC were negative, no significant correlations were found between performance and any variability measurement.

The results suggested that for males, athletes with better performance had lower variability in their...
movement patterns. Performance was associated with variability in shoulder, trunk, hip, and knee joint angles. The results suggested that male throwers with better performance had better consistency across the joints that make a major contribution to discus delivery. For females, although the correlations were negative, a lack of statistical significance suggested these linear correlations were not strong in females.

Inter-individual and intra-individual variability exists widely in sports [2]. Previous studies have demonstrated that during certain sports maneuvers, skilled individuals had lower variability in key techniques compared to less skilled individuals, and that variability decreased with practice and learning [2]. On the other hand, some other studies suggested elite athletes might increase variability to give the body flexibility in response to changes in movement constraint [2]. Considering discus throwing is a closed skill with little perturbation from the environment, the results for male throwers supports the notion of better movement consistency in skilled athletes. In addition, it should be noticed that the data were collected during competition, and the goal of these athletes was to achieve maximum performance instead of obtaining new techniques. Therefore, it appears that whether athletes could replicate their trained techniques during competition is important.

No significant correlation between performance and variability in females suggests variability might be not only sports specific but gender specific. Previous studies found that the magnitude of ASS, SHS, and TFBT angles at critical instants were associated with performance in females, while only SHS angle was correlated with performance in males. The authors suggested that females tended to rely on effective technique while males may have a relative homogenous technique [1]. The gender disparity might be caused by different throwing styles and physical characteristics between males and females. Based on the postulations that male throwers have a more homogenous technique, it is expected that better male throwers will have better consistency in replicating the technique. Therefore, it is more likely to find negative correlations between variability and performance in males than females.

**CONCLUSIONS**

Significantly negative correlations between technique variability and performance were found in elite male but not female discus throwers during competition. The disparity between genders might be caused by different technique patterns and physical capacities. The study suggested reducing motion variability may be an important goal for discus training in males.

**REFERENCES**


**ACKNOWLEDGEMENTS**

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Table 1. PCC and P values between performance and mean SD of each angle for males

<table>
<thead>
<tr>
<th></th>
<th>ASS</th>
<th>ASE</th>
<th>SHS</th>
<th>RHF</th>
<th>LHF</th>
<th>RKF</th>
<th>LKF</th>
<th>TFBT</th>
</tr>
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<tbody>
<tr>
<td>PCC</td>
<td>-0.44</td>
<td>-0.63</td>
<td>-0.59</td>
<td>-0.58</td>
<td>-0.57</td>
<td>-0.65</td>
<td>-0.47</td>
<td>-0.59</td>
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<tr>
<td>P Value</td>
<td>0.07</td>
<td>&lt;0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>0.05</td>
<td>0.01</td>
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Table 2. PCC and P values between performance and mean SD of each angle for females

<table>
<thead>
<tr>
<th></th>
<th>ASS</th>
<th>ASE</th>
<th>SHS</th>
<th>RHF</th>
<th>LHF</th>
<th>RKF</th>
<th>LKF</th>
<th>TFBT</th>
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<tbody>
<tr>
<td>PCC</td>
<td>-0.33</td>
<td>-0.44</td>
<td>-0.25</td>
<td>-0.24</td>
<td>-0.19</td>
<td>0.11</td>
<td>-0.28</td>
<td>-0.43</td>
</tr>
<tr>
<td>P Value</td>
<td>0.23</td>
<td>0.10</td>
<td>0.37</td>
<td>0.40</td>
<td>0.49</td>
<td>0.69</td>
<td>0.32</td>
<td>0.11</td>
</tr>
</tbody>
</table>

PCC: Pearson correlation coefficient; ASS: arm-shoulder separation angle; ASE: arm-shoulder elevation angle; SHS: shoulder-hip separation; RHF: right hip flexion angle; LHF: left hip flexion angle; RKF: right knee flexion angle; LKF: left knee flexion angle; TFBT: trunk forward-backward tilt angle.