AN EXAMINATION OF GROUND REACTION FORCES OF THREE POLE VAULT TAKE-OFF STYLES

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INTRODUCTION

- The take-off is regarded as the most important phase in the pole vault.
- There is an extensive amount of research on pole-vault velocity and take-off angles, and their effect on maximum vertical height.
- However, there is a scarcity of information regarding ground reaction force.
- Numerous pole vault techniques have emerged since the late 1940s when fiberglass poles were introduced.
- A free take-off happens when the pole vaulter takes off while the pole remains unladen and the take-off foot is just behind the top hand at the moment that the foot leaves the ground.
- The terms free take-off, pre-jump, and out take-off have been used interchangeably. For this research project the term out take-off will be used.
- Taking off slightly further away from the vault box (out take-off) rather than directly under the top hand (under take-off), or past the top hand (under take-off), may result in less energy lost due to braking forces and greater propulsive forces.
- The purpose of this study was to compare ground reaction forces of pole vault take-offs when the take-off foot is out, on, and under the top hand hold position.

METHODS

Participants
- Fifteen pole vaulters and multi-event athletes from North Dakota State University volunteered to participate in the study.
- Seven of those athletes (six male and one female) met the criteria of having five or more jumps in at least two of the three categories of out, on, and under during the study.

Procedures
- Data was gathered during normal practices. The participants were allowed to complete their normal warm up routine. Testing started when the pole vaulters got back to their 12 step approach run.
- A bungee cord was stretched between the stands at six inches over the subject’s personal best height in replace of a crossbar. Only jumps during which the pole vaulter was able to complete a full jump, swing to vertical, and make an attempt at the bungee were analyzed.
- Prior to the first vault attempt “On” steps were measured by standing on the ball of the take-off foot and having the top hand directly over their take-off foot. This location was marked and considered zero. On jumps were defined as having a range 0.010254m, out jumps were any jumps where the take-off foot was greater than .0254m from the on step, and under steps were jumps where the take-off foot was less than 0.0254m of the on step.
- Dartfish software was used to measure the steps and an AMTI Accupower force plate was used to analyze the ground reaction forces at a sampling rate of 2,400 Hz.
- The force plate was fixed in a raised runway between 3.048m and 3.9624m from the back of the planting box.

Analysis
- Of the 226 jumps collected from the seven subjects, 24 of 24 out, 42 of 54 on, and 42 of 66 under jumps (a total of 106) were analyzed.
- Separate mixed model ANOVAs were run on each outcome measure with jump type (group) and vaulter (subject) treated as fixed effects and the individual jumps treated as random effects.
- The analyses compared: vertical force, anterior (braking) force, posterior (propulsive) force, medial force, and lateral force for all jumps that were on, under and out.
- Statistical significance was set at p<.05.

RESULTS

- Means and standard deviation are listed in Table 1.

Table 1. Means and Standard Deviations of Out, On and Under Take-offs

<table>
<thead>
<tr>
<th></th>
<th>Mean (BW)</th>
<th>SD</th>
<th>p</th>
<th>Mean (BW)</th>
<th>SD</th>
<th>p</th>
<th>Mean (BW)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical</td>
<td>-0.879</td>
<td>0.169</td>
<td>.007</td>
<td>0.198</td>
<td>1.087</td>
<td>.211</td>
<td>0.435</td>
<td>.221</td>
</tr>
<tr>
<td>Anterior</td>
<td>0.157</td>
<td>0.036</td>
<td>.135</td>
<td>0.043</td>
<td>0.118</td>
<td>0.037</td>
<td>0.172</td>
<td>.032</td>
</tr>
<tr>
<td>Medial</td>
<td>-0.009</td>
<td>0.012</td>
<td>.022</td>
<td>-0.014</td>
<td>0.032</td>
<td>.032</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- No significant differences were found between the take-offs for any of the force parameters (See Table 2).
- Significant differences were found between subjects for all of the force parameters (See Table 2).

Table 2. Mixed Model ANOVA Results

<table>
<thead>
<tr>
<th>Differences between take-offs</th>
<th>F</th>
<th>p</th>
<th>Differences between subjects</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical</td>
<td>18.94</td>
<td>.0001</td>
<td>Anterior</td>
<td>62.92</td>
<td>.0001</td>
</tr>
<tr>
<td>Medial</td>
<td>34.68</td>
<td>.0001</td>
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</tr>
</tbody>
</table>

DISCUSSION

- Although no significant differences were found between the different take-off types, it is important to note that posterior (propulsive) force was nearly significant.
- It is also interesting that:
  1) Vertical force increased from take-offs that were out to under.
  2) Anterior (braking) force increased from take-offs that were out to under.
  3) Posterior (propulsive) force decreased from take-offs that were out to under.
- The increase in braking force from out to under take-offs was expected. As the pole vaulter takes off further toward the pit it makes sense that they would be forced to slow down. This would increase braking force and decrease the amount of strain energy stored in the pole, which could decrease performance.
- The decrease in propulsive force from out to under take-offs was also expected. As the pole vaulter takes off further towards the pit it makes sense that they would not be able to push forward with as much force. This would decrease the amount of strain energy they could store in the pole, which could decrease performance.
- Although the forces were normalized to body weight, there were significant differences between the subjects for all of the force parameters, indicating that there was considerable variation between the pole vaulters with-in the different types of take-offs.
- During the testing procedure, it was observed that upper-class athletes were more consistent with their take-off being on or out, whereas the underclassmen were consistently under.

CONCLUSIONS

- There were no significant differences in the force parameters between the various types of take-offs.
- There were significant differences between the subjects for each force parameter.
- Although no significant differences were found in this study between the take-off styles, trends indicated that take-offs in the out position will result in more propulsive force and less braking force.
- The greater propulsive forces and lower braking forces provided by an out take-off could result in greater jump heights.
- The experience of the pole vaulter may affect their ability to take-off from the out position.
- Future research should examine how possible differences in force parameters effect performance (clearing various heights).

Acknowledgment
The researchers thank the North Dakota State University pole vaulters for participating in this study. They also thank Curt Doetkott for his help with the statistical analyses.