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

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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. The take-off is regarded as the most important phase of the pole vault yet there is an insufficient amount of research on the ground reaction forces of the pole vault take-off. At this time there is not any scientific research comparing ground reaction forces between take-offs that are out, on and under the top hand hold. A total of 108 jumps with a take-off from a force plate were used for analyses. The jumps were put into categories of out, on and under and analyzed by Accupower and Dartfish software. Separate mixed modal ANOVAs were applied ($p<.05$) for comparison between jump types. No significant differences were found in ground reaction forces between the three take-off types.

KEY WORDS: Accupower, Dartfish**,** Force plate

INTRODUCTION: 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. Previous research focused on methods to minimize energy loss during the pole vault to increase maximum height (Barlow, 1973; Gros, 1982). 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. Barlow (1973) and Plessa et al. (2010) were the only studies found that measured ground reaction force and ground contact time of the take-off leg in the pole vault.
Numerous pole vault techniques have emerged since the late 1940s when fiberglass poles were introduced. Vital Petrov and his creation of the Petrov/Bubka pole vault model produced the world record for both men and women in the pole vault. In his book, From Beginner to Bubka, Alan Launder discussed the Petrov model in detail. A popular aspect of the Petrov model is the free take-off. A free take-off happens when the vaulter takes off while the pole remains unloaded (Launder & Gormley, 2008). The take-off foot is just behind the top hand at the moment that the foot leaves the ground. There is some confusion with the terminology because the terms free take-off, pre jump, and out take-off have been used interchangeably. For the purpose of this discussion, the term out take-off will be used. The model suggests that by taking off slightly further away from the vault box rather than directly under the top hand, less energy will be lost and the vaulter will be taller during the take-off. It appears no published research has measured the difference in ground reaction force of the take-off with the take-off foot on, under, or out of the top hand hold position in the pole vault.

METHODS: Fifteen healthy male and female Division I college pole vaulters and multi-event athletes from North Dakota State University (NDSU) 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. “On“ steps were measured prior to the vault attempt and marked as zero. On jumps were defined as having a range 0±.0254m, out jumps were any jumps greater than .0254m from the on step, and under steps were jumps that were less than on 0.0254m of the on step. The pole vaulters were allowed to complete their normal warm up routine, testing started when the pole vaulters got back to their 12 step approach run. Only jumps during which the vaulter was able to complete a full jump, swing to vertical, and make an attempt at a bungee were analyzed. The bungee height was placed at a height of six inches over the subject's personal best height.

Subjects on steps were tested by standing on the ball of their take-off foot and having their top hand directly over their take-off foot. A video of the on step was recorded with Dartfish software (Version 5, Alpharetta, Georgia, USA). An AMTI Accupower force plate and software (Advanced Mechanical Technology Inc, Watertown, MA, USA) were used to analyze the ground reaction forces at a sampling rate of 2,400 Hz. No more than 10 jumps and no fewer than five jumps were collected from each pole vaulter at each of their four practices. All the jumps were organized into categories of on, under and out. The force plate was fixed in a raised runway between 3.048m and 3.9624m from the back of the box. A tartan surface was placed over the runway and the force plate so the force plate was level with the raised runway. All trials were recorded with a Sony DCR-HC52 video camera filming at 30 frames per second. Out of the 226 jumps collected from seven subjects, 24 of 24 out, 42 of 54 on, and 42 of 66 under jumps (a total of 108) were analysed. Dartfish software was used to determine the difference between the subjects on step and take-off step in meters. Ground reaction force parameters were consistent with the study by Plessa et al. (2010), in which vertical (Fz), anterior-posterior (Fy), and medio-lateral (Fx) were collected in newtons and were converted to body weight. All the data were entered into Statistical Analysis Software (SAS Institute Inc.) for statistical analyses. A p-value < 0.05 was used to determine statistical significance. 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. F-tests were obtained on groups and subjects and follow up t-tests were run on the least-squares means (LS-means) for all significant F-tests. The tests compared: vertical force, breaking force, propulsive force, medial force, and lateral force for all jumps that were on, under and out.

RESULTS: Means and standard deviation are listed in Table 1. No significant differences were found between take-offs that are out, on, and under in Vertical ($F=0.54$, $p=0.65$), Anterior ($F=2.34$, $p=0.30$), Posterior ($F=18.65$, $p=0.05$), Lateral ($F=0.85$, $p=0.54$), and Medial ($F=0.58$, $p=0.63$) force parameters.

Table 1
Mean and Standard Deviation of Out, On, and Under Take-offs

Mean and Standard Deviation						
Forces (BW)	Out	±	On	±	Under	±
Vertical	3.591	0.496	3.856	0.390	3.939	0.435
Anterior	-0.879	0.169	-1.009	0.198	-1.087	0.211
Posterior	0.157	0.036	0.135	0.043	0.118	0.037
Lateral	0.286	0.138	0.380	0.170	0.407	0.172
Medial	-0.009	0.012	-0.009	0.022	-0.014	0.032

DISCUSSION: The findings are consistent with Barlow (1973) and Plessa et al. (2010). 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 (breaking) force increased from take-offs that were out to under; and 3) Posterior (Propulsive) force decreased from take-offs that were out to under.

McGinnis (1989) stated that it can take more than 15 years for athletes to become proficient in the pole vault. 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. Of the seven subjects used, only two participated in the sport for fewer than five years. Pole vaulters in this study ranged in personal best heights from 3.8 meters to 5.11 meters, compared to Barlow (1973), 3.9 m to 5.50 m.

CONCLUSION: The findings are important because there is little research on pole vault ground reaction forces and take off location. Although statistically significant differences were not found in this study, propulsive force was found to be close to significant. It is important to remember that ground reaction forces at the take-off are only a part of a successful pole vault performance. The study provides information about ground reaction forces at different take off locations which will be useful for coaches and future research of the take-off in the pole vault. The greater propulsive forces provided by an out take-off could result in greater jump heights. It is also noteworthy for a coach to be aware that younger more inexperienced pole vaulters may have a more difficult time achieving a take-off in the out position.

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