# INSIGHTS OF TAKE-OFF OF GROUND REACTIONS FORCE IN HIGH JUMP

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**KEYWORDS:** High Jump, Take-off, Ground Reaction Forces.

**INTRODUCTION:** The take-off plays an important role on the high jump (HJ) performance, since it is there where the trajectory of the centre of mass is defined (Tellez, 1993) in order to achieve the maximum possible height and clear the bar (Dapena, 1988). The literature has presented several studies using kinematic parameters, however there are very few studies using dynamic parameters to evaluate the take-off (Coh & Supej, 2008).
In contrast to other jumps, the HJ presents an increased complexity due to the curvilinear approach-run pathway, imposing a three-dimensional analysis of the movement. On the other hand, the point where the jumpers perform the take-off differs considerably for different subjects. For those reasons research presented in the literature is fundamentally based in the kinematics of the approach-run and take-off. Although great knowledge was achieved in the kinematic of HJ, very few studies can be found concerning the ground reaction forces (GRF). However the knowledge of the GRF pattern enables a more thorough evaluation of the jumper technique and efficiency. The purposes of this study were (i) to evaluate the HJ take-off technique using force plate data based on the characterization of the GRF pattern and (ii) definition of take-off GRF profiles as function of technical and conditional characteristics of different athletes.

**METHOD:** Nine male high jumpers from different levels (age: 18.7±3.7 years old; height 1.81±0.07 m; body mass: 71.3±6.7 kg, personal record: 1.91±0.2 m) took part on this study. A strain gauge force plate (Bertec 4060-15) placed on the take-off point and sampling at 1000 Hz was used to collect the GRF data during HJ take-off. The force plate was synchronized with a high-speed camera sampling at 1000 Hz by photocells placed 5 m before the take-off point. Each jumper performed the trials in accordance with the official rules of HJ competition. GRF data was treated in software developed in Matlab environment. Firstly the GRF was corrected by a rotation matrix taking into consideration the foot angle relatively to the HJ bar. Then, global and local maximum and minimum in each component of GRF, their time of occurrence, impulses and contact time were determined. Finally data were resampled over new time vector between [0; 1000] and scaled to their maximum value to obtain GRF profiles for each jumper during take-off.

**RESULTS:** The maximum heights that the jumpers cleared were between 1.75 and 2.05 m with a mean value of 1.83±0.13 m. The mean take-off time was 0.197 s±0.02 s, with the minimum and maximum values between 0.169 s and 0.228 s, respectively. A mean angle of 40.5±10.2º was observed between the foot and the HJ bar. The vertical GRF varied between 1170 N and 4110 N. We found two different vertical GRF profiles, one with two peaks, and other with three peaks. The peak values in this component for athletes with two peaks was 2920.0±371.2 N, and 3027.8±445.9 N, while for those with three peaks, 3400.8±404.7 N, 3118.1±460.7 N and 2605.2±257.6 N. Antero-posterior forces ranged from -2418 N for the breaking phase and 152 N for the propulsive phase. The profile of this component presents only negative values. The medio-lateral forces varied between 1026 N and -589 N.

**DISCUSSION:** Results obtained for GRF are much lower than those presented in the literature, probably because our sample is composed by young level athletes with only two national elite level jumpers.
In contrast to other studies, the GRF were corrected and changes were perceived in the magnitude of the antero-posterior component, and in the pattern of the medio-lateral component, while the vertical component was kept unchanged.
Our results show that some features resulting from the approach-run can be observed in the take-off. When the athletes perform a correct curve the forces in the antero-posterior component were always negative towards inside the curve which means that the jumper do not generate additional force to go outward (into the mat). Motions from the leading leg and arms were evaluated in the medio-lateral component, identified by the change in the sign of the force. Although the magnitude intensity of the forces is low, they are important to understand how the jumper is managing its free limbs. The actions of the take-off leg can be observed particularly in the vertical GRF. We noted that when the time of occurrence of maximum and minimum points particularly in the vertical and medio-lateral components matched there is a strong association with an effective take-off action.
Concerning the GRF profiles we found two different kinds of profiles. Figure 1 represents the profile with two peaks in the vertical GRF, while in Figure 2 it is shown the three peaks profile. The most reactive athletes show two peaks in the vertical component and, contrary to the other profile, show a deep increase of forces in the last peak. The antero-posterior component is similar in all the profiles. With regard to the medio-lateral component, large variation is found. These results allowed the determination of subject specific take-off profile. Each one reflects the technical and conditional characteristics of a given athlete. If the sample was larger it is likely that more different profiles would be found. In the future, GRF should be combined with kinematics in order to obtain more insights about the behaviour of GRF in HJ.

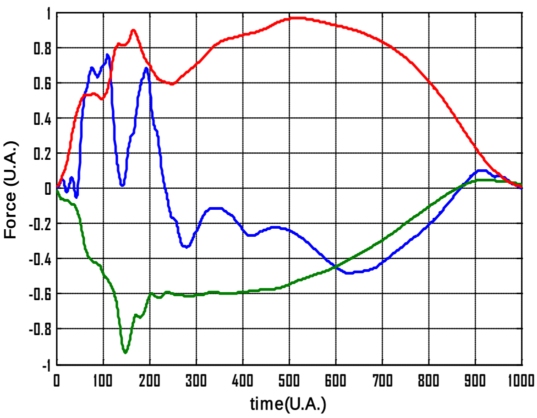


**Figure 1. Take-off profile of ground reactions forces of athlete S1. Mean curves from different trials.**

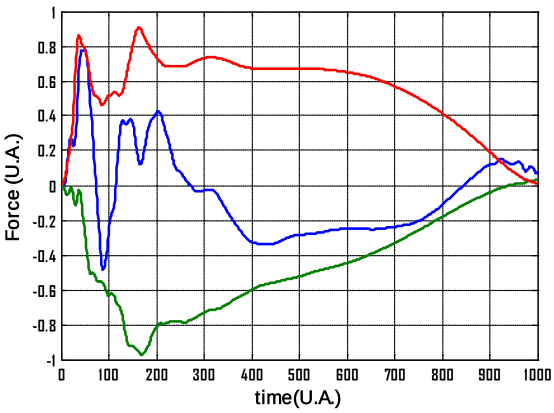


**Figure 2. Take-off profile of ground reactions forces of athlete S6. Mean curves from different trials.**

**CONCLUSION:** The main conclusions of this work are that GRF can be used to perform technical evaluation and that each jumper has specific take-off characteristics resulting from its technical and conditional characteristics.

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