# GROUND REACTION FORCES OCCURING DURING THE DELIVERY STRIDE OF JAVELIN THROWING.

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Five male javelin throwers (mean ± SD: age 24 ± 3 years; height 1.83 ± 0.06 m; body weight 888 ± 117 N) performed outdoors. Two Kistler force platforms were mounted beneath an outdoor polyflex runway (0.017 m depth) with positioning adjustment for each subject's delivery stride length. For the back foot the mean (±SD) peak vertical ground reaction force was 2.31 ± 0.41 BW, and maximum total force was 2.36 ± 0.50 BW. For the front foot the mean peak vertical force was 5.63 ± 1.31 BW, the braking force was 4.50 ± 0.96 BW and maximum total force was 7.05 ± 1.57 BW. At the beginning of the delivery stride, when the back foot contacted the ground, the mean peak vertical loading rate was 115 ± 35 $BWs^{-1}$ which was less than the front foot loading rate of 192 ± 64 $BWs^{-1}$.

**KEY WORDS:** athletics, track, force, javelin, loading rate.

**INTRODUCTION:** Javelin throwing is an event that places extremely high physical demands on participants as the body's musculature generates the force to project the javelin into flight. These demands result in a high incidence of injury with the throwing arm, back and legs most commonly involved as reviewed by Deporte & Van Gheluwe (1988), and supported by more recent studies (Hurrion et al. 1998; Schmitt et al. 2001). In a comparison of club, county (regional), and national javelin throwers Hurrion et al. (1998) reported that 91% of javelin throwers had sustained an injury which prevented participation in training or competition for seven days, and that there was an increased incidence of injury at national level (national:100%; club:88%), with the most commonly injuries the back (32%), knee (26%) and elbow (28%). A major factor likely to be contributing to back and leg injuries is the high forces generated at the feet during the final delivery stride of the javelin throw. In 1988 Deporte & Van Gheluwe, reported very high ground reaction forces occurring at the back cross-over leg foot in the final delivery stride. And subsequently in a second javelin throw, the front push off leg foot ground reaction forces were monitored. The aim of the current study was to record the ground reaction forces occurring at both the back and the front foot during the delivery stride of a single throw. Such results would establish whether such high ground reaction forces still occurred in view of probable changes in coached technique over the years. Also, such measurements within the same delivery stride would reduce the likelihood of throwers being able to adapt technique to focus on either the front or back foot during the delivery stride of the throw, and therefore possible influence the magnitude of recorded force data.

**METHODS:** The five throwers gave written informed consent to participate in the study following an explanation of the testing procedure and familiarisation with the recording equipment. Their physical characteristics were mean ± SD: age 24 ± 3 years; height 1.83 ± 0.06 m; body weight 888 ± 117 N. The participants wore their own personal throwing shoes and clothing and performed the throwing without any additional torso supports. During the testing period the weather conditions were windless with temperatures in the range 22 -27°C. All trials were carried out over a period of one month during the competitive athletic season. Two 0.6 m by 0.4 m Kistler type 9851 piezoelectric force platforms (Kistler, Alton, UK) were situated within a section of a specially designed outdoor polyflex surface (International Amateur Athletics Federation Standard). The two platforms were recessed into the track surface and were covered with a 0.017m polyflex layer adhered to an aluminium sheet which was mounted on to the top plate of each force platform. A specially designed rig allowed the force platforms to be positioned to ensure that the back foot landing and front foot landing during the same delivery stride of a throw could be measured. The force platform positions' were adjusted relative to each other to match each subject's delivery stride length. Three delivery strides when both the back foot and front foot hit the two platforms and a good throw occurred were analysed for each subject. The distance of each throw of an 800g javelin was

recorded at ground level. The acquired force platform data were converted to digital form and sampled at 500 Hz for a three-second period using Provec 5.0 software (Orthodata, Ludenschneid, Germany) running on an IBM compatible personal computer (Viglen, Alperton, UK) fitted with a 12 bit analogue to digital converter (Amplicon, Brighton, UK). Force data were analysed to determine peak force levels occurring during both back and front foot strike using visual identification of peak maxima (i.e. without the use of programmed peak identification). Peak data were calculated in terms of each individual's body weight and peak vertical impact loading rates calculated. The peak impact vertical loading rate was determined by dividing the maximum force occurring following initial foot contact by the time of occurrence of this peak force relative to initial touchdown. For the group of javelin throwers, mean descriptive statistics were calculated. Dual support time was calculated to indicate when both the back and front foot were in contact with the ground (time is + ms) or the separation between back and front foot contact (time is – ms).

**RESULTS:** The front foot mean peak vertical ground reaction force of 5.63 BW (range 3.7 to 7.3 BW), and maximum front foot total force of 7.05 BW (range 4.8 to 9.3 BW) were large as the maximum effort of the javelin release was accomplished with the involvement of major muscle groups, particularly in the front leg. Table 1 shows the mean peak forces occurring at the front foot for the group of javelin throwers. These values were derived from thirteen deliveries when both the back and front foot in the same delivery stride hit the force platforms. Due to the physical effort and exhausting nature of javelin throwing only one delivery stride when both feet struck platforms in the same delivery stride was included for one subject. Data for back foot forces are not presented for the horizontal plane as during analysis it became evident that occasional rotation of the foot could result in misleading peak maxima interpretation for the group as a whole.

**Table 1.** Mean peak ground reaction forces (±SD) recorded at the front foot during the delivery stride of javelin throwing.

| Force | BW | Newton |
|---|---|---|
| Vertical impact | 2.53 ± 1.01 | 2246 ± 1081 |
| Vertical peak | 5.63 ± 1.31 | 4852 ± 1122 |
| Braking | 4.50 ± 0.96 | 3864 ± 743 |
| Propulsive | 0.26 ± 0.09 | 229 ± 85 |
| Medial | 0.77 ± 0.36 | 677 ± 339 |
| Lateral | 0.59 ± 0.18 | 515 ± 176 |
| Total | 7.05 ± 1.57 | 6053 ± 1210 |

In comparison, the forces that occurred following the back foot strike at the beginning of the delivery stride were much lower with a mean (±SD) peak vertical ground reaction force of 2.31 ± 0.41 BW (2002 ± 422 N), and maximum total force of 2.36 ± 0.50 BW (2032 ± 442 N). The mean javelin throw distance was 53.4 m (SD 5.4 m) with a range of 48.7 m to 66.8 m. In the right-handed javelin thrower (Figure 1), following back foot contact the vertical force rose relatively slowly to a peak value of 2500 N and then fell (Figure 2). The braking force of approximately 1000N occurred as the thrower slowed in preparation to release of the javelin. With front foot contact there was a relatively high braking force of just less than 4000 N as the body prepared to throw the javelin before the scratch line was reached and the thrower's speed decelerated. This was associated with lateral-medial forces of approximately 800 N. At

front foot heel strike, the initial peak impact force was followed by a period of increased loading with a final high peak vertical force of around 4500 N.

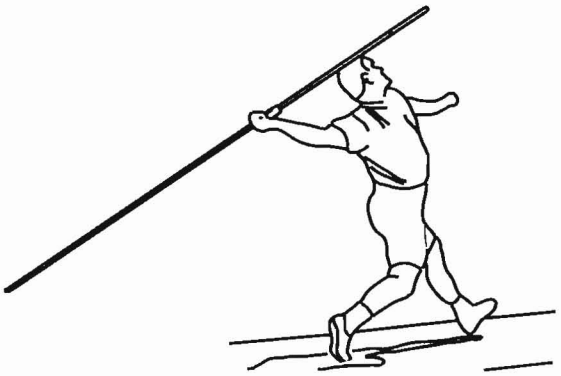

**Figure 1.** The position of the limbs during the javelin final delivery stride.

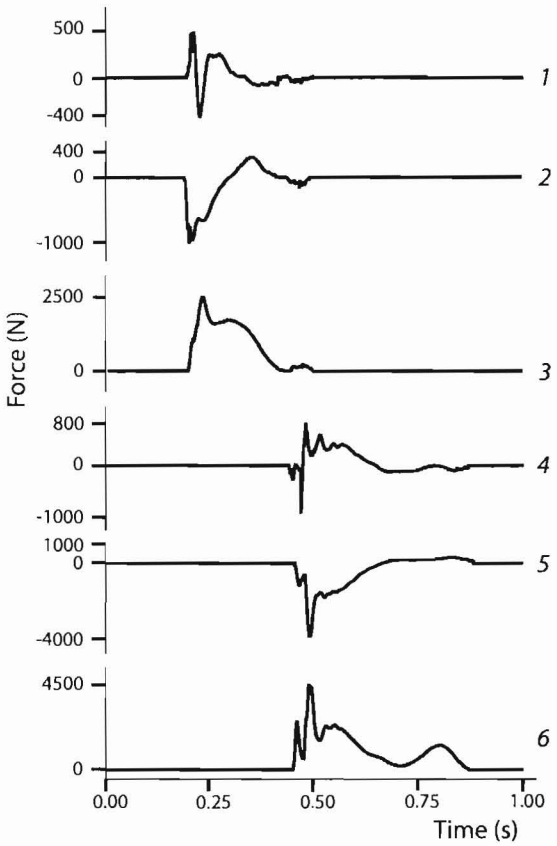


**Figure 2.** Delivery stride ground reaction forces of a right-handed javelin thrower. Right back foot: 1. Medial-lateral; 2. Braking-propulsion; 3. Vertical. Left front foot: 4. Lateral-medial; 5. raking - propulsion; 6. Vertical.

At the front foot heel strike the mean peak vertical impact loading rate (±SD) was 192 ± 64 $BWs^{-1}$. This was 66% more than the back foot mean peak vertical impact loading rate of 115 ± 35 $BWs^{-1}$ which occurred at the beginning of the delivery stride when the back foot made contact with the ground. During the delivery stride the mean maximum total force sum (±SD) for the back and front foot together was 9.41 ±1.38 BW for the group of javelin throwers with a range of 7.6 to 11.4 BW.

**DISCUSSION:** The results indicate the particularly large mean total ground reaction force of 7.05 BW which occurred at the front foot during the delivery stride. Also, the significance of the peak vertical force component and vertical impact component for which the mean values were 5.63 BW and 2.53 BW respectively. Furthermore, the mean impact peak was smaller than the vertical peak force for the front leg. Comparison with the elite study of Deporte & Van Gheluwe (1988) was difficult. The shape of the vertical force-time curves suggest that considerable changes in shoe design and throwing technique are likely to have modified ground reaction force measures in the interim years, particularly the ratio between impact and peak vertical forces. In Deporte & Van Gheluwe's study the mean maximal vertical front foot force reported was 7.2 BW and back foot force 5 BW which are greater than mean vertical forces recorded in this study. In this study the mean maximal total force was 7.05 BW for the front foot and 2.36 BW for the back foot suggesting that changes in technique and equipment have influenced ground reaction force measures. In comparison when plantar pressure insole methodology was utilised values of 2.75 BW and 2.65 BW for the front and back foot were reported by (Bartlett et al. 1995).

**CONCLUSION:** The large ground reaction forces occurring in javelin throwing are confirmed. If the health and welfare of athletes is important further experimental investigation into the relationship between ground forces and its variation with footwear, throwing technique, coaching practice and training should aid in the identification of potential contributing factors to injury and in injury prevention.

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