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AN EMG PROFILE OF LOWER LIMB MUSCLES DURING LINEAR GLIDE AND STANDING SHOT PUTTING

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The purpose of this study was to provide a descriptive analysis of the phasic muscle activity of 8 lower limb muscles during performance of the shot put field event in track and field athletics. Six shot putters performed 3 standing and 3 full linear glide technique throws. Electromyography (EMG) of 8 lower limb muscles was recorded during the trials and the distance thrown was also measured. A comparison between standing and glide techniques are important from a coaching perspective. An increase in peak muscle activity of the Rectus Femoris was observed between the glide and standing throw, all other lower limb muscles showed no significant increases between the techniques. Results show significant increases between performances of standing and glide throws in female athletes however the mean differences were smaller in the male athletes.

KEY WORDS: EMG, electromyography, athletics, thrower, shot put.

INTRODUCTION: There are two main techniques for the shot put and frequent comparisons have been made between the linear, known as the glide, and the rotational techniques (Bosen, 1985; Stepanek, 1987). Stepanek (1987) concluded that both techniques are similar in both “mechanical principles and characteristic features”, however the preparation phases of both techniques have of different executions. The author mentions that even though the rotational technique could have a better performance potential, the glide technique is usually used by the winners in elite sports events. This can be due to the fact that the technique is less demanding on the thrower and more training time would be required for the rotational technique (Stepanek, 1987). Athletes frequently practice standing throws as a part practice for the glide throw. Standing throws are used in warm-up at competition as well as in training for technical refinement of release parameters.

Extensive research has been done into the biomechanics of shot put technique; one such review summarizes these results, the main emphasis being on the glide technique (Zatsiorsky, Lanka, & Shalmanov, 1981). Despite this extensive research, there is limited research available on leg muscle activity during shot putting. Previous studies have examined EMG of selected muscles in the arms (Hermann, 1962; Terzis, Karampatsos, & Georgiadis, 2007), but only one study was found on the EMG of the Vastus Lateralis (VL) in pre-season and competition period (Kyriazis, Terzis, Boudolos, & Georgiadis, 2009). Given the lack of research on EMG on lower limb muscles in the shot put and the crucial importance of the legs muscles in performance of the event, an analysis of leg EMG patterns is merited to provide initial base line data for the event.

The primary aim of this study is to identify the phasic muscle activity during shot put. Knowledge of muscle activations of the lower limbs during shot put should be useful from a coaching perspective for improvement in performance. It is important to note that although the athletes in this study were national level throwers, the phasic muscle activity during the throw will be comparable to that of elite athletes. Given the importance of the standing throw as a specific practise activity, an examination of EMG measures could indicate important similarities or differences between the glide and standing throws. Increased understanding of these differences or similarities could have important implications for coaching and training in the event. Therefore a secondary aim of this study is to compare peak EMG in both the standing and glide throws.

METHODS: Six volunteers, 3 females (age 19 ± 0.8 years, height 166.3 ± 7.4 cm, mass 73.67 ± 9.98 kg; mean \pm SD) and 3 males (age 20 ± 0.5 years, height 187.2 ± 3.8 cm, mass 77.5 ± 3.3 kg; mean \pm SD), who were injury free at the time of testing, participated in the study. All participants were national level shot putters or multi-eventers and were therefore

accomplished experienced in linear glide shot put technique. Ethical approval was granted by the local University Research Ethics Committee and all participants completed an informed consent form before testing.

Participants performed a standardised warm-up, consisting of 2 minutes of running at a self-selected, comfortable pace followed by short dynamic stretches and drills (forward and sideways skips with arm swings, high knees, hamstring stretch, bodyweight squats, and lunges). EMG electrodes were attached after the warm-up. Skin was prepared and electrodes were positioned according to SENIAM recommendations (Hermens). EMG signals were obtained using the Trigno™ Wireless EMG (Delsys, 2015), and electrodes were attached to the Rectus Femoris (RF), Biceps Femoris (BF), and the Medial and Lateral Gastrocnemius (MG, LG respectively) on both the right and left legs. Each participant then performed submaximal attempts using standing and glide technique shot putts, followed by 3 maximal trials at standing shot putts and 3 maximal trials at full linear glide technique during which EMG was recorded. The shot put trials were performed indoors, on a specially made standard size circle. All participants were right handed throwers, so their right leg was the single support leg during all throws. All throws were also recorded with a high speed (HS) video camera, Casio EXF1, recording at a frame rate of 240 Hz and this was used to identify key kinematic events in the throws from the start of the movement through to release point.

After acquiring the data from the wireless EMG device, offline analysis was performed using a combination of Delsys proprietary software to extract the data, and custom Matlab code to analyse results. All EMG data was processed by removing any DC offset and performing full-wave rectification. Peaks of all EMG signals were also identified. High speed videos of the throws were analysed to identify the duration of the throw, highlighting the mid-point as the time in which the right leg landed after the glide. The EMG of the RF of the right leg was also analysed to identify the glide phase beginning; silence in the EMG signal was seen during take-off of the back leg before landing back into the standing throw position (Kyriazis et al., 2009). Student t-tests were performed to analyse the significance of the differences between the standing and glide throw in performance and peak EMG measures.

RESULTS: Table 1 shows the mean results (\pm SD) for distance of standing throw and the full linear technique throw. A mean percentage difference of 4.4% was found between the male participants however this difference found to be a statistically significant improvement when moving from standing throw into a glide ($p=0.286$). By contrast the female participants demonstrated a statistically significant improvement between their standing throw and glide performances ($p<0.001$) with a mean percentage difference of 9.65% between standing and glide throws.

Table 1
Shot Put Results

| | Male (7.26 kg) | Female (4 kg) |
|-----------------------------------|-----------------------|----------------------|
| Full Technique Glide Distance (m) | 8.97 \pm 1.01 m* | 10.26 \pm 1.13 m |
| Standing Throw Distance (m) | 8.56 \pm 0.71 m | 9.27 \pm 0.97 m |
| % Difference | 4.4 | 9.65 |
| Student t-test (p value) | 0.286 | < 0.001 |

*One throw rolled off the athletes' fingers resulting in a throw of approximately 3 m less than previous two throws.

The rectified EMG signals are shown in Figure 1 and this highlights where the muscles were active during the phases of the throw. The phases of the throw were identified using a combination of the EMG signals and the HS video clips. The silence in the EMG for the RF was the take-off of the back leg into the glide phase before landing in the power position. It can be seen the RF becomes active again just before landing in the power position in preparation for the final drive of the legs through the standing throw position. The peaks of the LG and MG were observed to be leading the peak of the RF and then the BF; these are the final drives of the legs as the foot turns to allow the hip to externally rotate forcefully before release. Finally the arm finishes the throw.

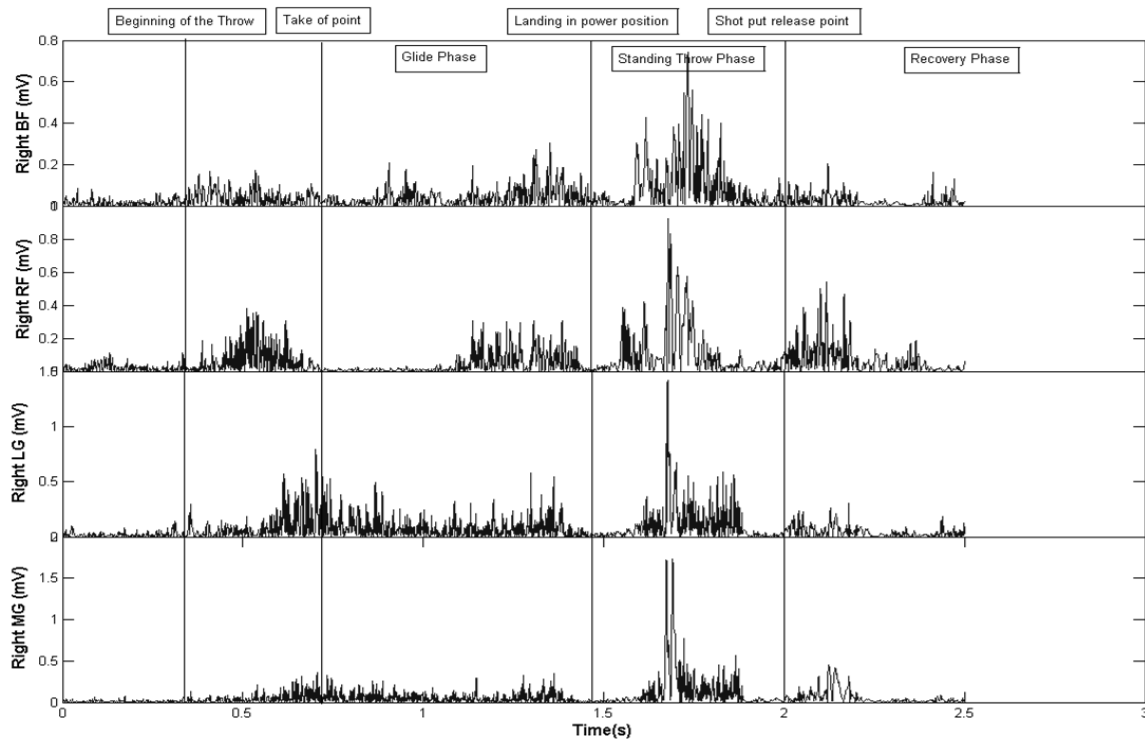


Figure 1: An example of the EMG activity of lower limb muscles during shot put (Dominant leg)

Table 2 shows the mean results (\pm SD) of the peak EMG values in both the glide and standing technique in RF, BF, LG and MG. There is a significant difference between glide and standing throw peak EMG of the RF. There is no significant difference between the standing throw and glide for the peak EMG of BF, LG and MG.

**Table 2
EMG Results of lower limb muscles**

| | Rectus Femoris | Biceps Femoris | Lateral Gastrocnemius | Medial Gastrocnemius |
|---------------------|-----------------------|-----------------------|------------------------------|-----------------------------|
| Peak EMG Glide (mV) | 3.27 \pm 1.99 | 1.61 \pm 2.03 | 1.26 \pm 1.5 | 1.88 \pm 1.81 |
| Peak EMG Stand (mV) | 0.91 \pm 0.87 | 1.74 \pm 2.01 | 1.16 \pm 0.92 | 1.26 \pm 1.01 |
| % Difference | 72 | -8 | 8 | 33 |
| Student T-test | p = 0.027 | p = 0.572 | p = 0.304 | p = 0.815 |

DISCUSSION: The results of this investigation generally showed significant increases in performance between standing throws and full throws in the female athletes. However, in the male athletes the increase in performance in the glide throw was poor; this can be attributed to one trial. The shot rolled off the athlete's fingers on release causing the release angle to be too large. The result was a throw approximately 3 m less than the other trials recorded. By ignoring this throw the results showed statistically significant increases similar to the female participants (p=0.01) in the student t-test.

The phasic muscle activity of the dominant leg of the thrower during the glide was highlighted over the various phases of the throw. A combination of the EMG signals and the HS video clips helped to identify the phases. It can be seen that the RF is very important for shot putters. As the thrower takes-off of at the back of the circle into the glide phase silence in the RF EMG signal is visible. Before landing in the power position in preparation for the final drive the RF EMG signal shows activity again. This activity remains for the latter phase of the throw through the standing throw position. This highlights the need for coaches to work on glide to standing throw phase with their athletes as this is an important part of the throw.

EMG results showed that the peak muscle activity of the lower limbs increased significantly for the RF when the athlete moved from a standing throw into a full linear glide technique throw. The peak EMG activity of the BF, MG and LG did not show any significant increases. Based on these data it appears that the end of the glide throw has similarities to the standing throw. This suggests that practise of the standing throw technique is useful for training purposes since it involves similarities in muscle activations.

A high peak EMG was observed in both the MG and LG prior to the release of the shot as the athlete was moving into full knee extension at this point of the throw. It can be seen that the peak occurs first in the MG and LG as the rear foot moves first, followed by the hip, which can be identified as the RF peak and finally the BF peak.

CONCLUSION: Results of this investigation suggest that the use of the standing throw technique will provide a practical basis for techniques development in a full linear glide throw. This is useful from a coaching perspective as the final stage of the glide is similar to a standing throw. The peak EMG results also show that the muscle activations are very similar in both techniques highlighting that the use of a standing throw in training activate the muscles in an appropriate way. More extensive analysis of the EMG signals of the lower limb muscles can be done to provide a greater insight into the phasic muscle activity during the glide.

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