CONTROL AND REGULATION OF GROUND REACTION FORCES DURING THE PULL-PHASE OF THE SNATCH AND CLEAN

Kristof Kipp[1] and Matthew D. Giordanelli[1]

Department of Physical Therapy, Marquette University, Milwaukee, USA[1]

The purpose of this study was to determine how weightlifters control and regulate ground reaction forces (GRF) as they perform the snatch and clean. GRF were recorded as six skilled weightlifters participated in a weightlifting competition. Statistical parametric mapping was used to compare the vertical GRF, horizontal GRF, and GRF angle time-series data from both lifts. The results highlight precise control of horizontal GRF, which did not differ between lifts. The vertical GRF during the snatch and clean differed significantly during the first 35% of the entire pull-phase, likely due to the mass difference (~20kg) between the lifts. The GRF angle time-series differed only slightly between lifts. Regulating only the vertical GRF may provide an advantage in that weightlifters can use the same coordination patterns and simple scaling of muscle activations for the lifts.

KEYWORDS: weightlifting, biomechanics, coordination patterns, statistical parametric mapping.

INTRODUCTION: Performance in the sport of weightlifting is determined by the combined mass a competitor can successfully lift in two lifts: the snatch and the clean & jerk. Sports scientists have investigated biomechanical characteristics of the two lifts to determine key performance indicators of weightlifting technique and performance (Baumann et al., 1988; Kauhanen et al., 1984; Kipp et al., 2012). The biomechanical variables examined in most previous studies are primarily related to the mechanics of the barbell during the entire pull-phase (i.e., first and second pull phase) of the snatch and clean (Garhammer, 1985; Gourgoulis, et al., 2000, Isaka, Okada, & Funato, 1996; Kipp et al., 2015; Stone et al., 1998). While these studies have contributed to the current understanding of snatch and clean biomechanics there is a relative dearth of information about the mechanics of the entire lifter-barbell system during these lifts.

The mechanics of the lifter-barbell system result from the externally applied ground reaction forces (GRF). Although analyses of GRF provide insights into the neuromuscular strategies used to control force direction of multi-joint systems (McNitt-Gray et al., 2013), relatively few studies have examined GRF during the snatch and clean (Baumann et al., 1988; Kauhanen et al., 1984). Kauhanen et al. (1984) reported significant differences between the discrete peaks GRF of elite and district level weightlifters during weightlifting movements. In addition, the same authors reported that the peak relative GRF during the first part of the pull-phase of the clean correlated with the barbell mass, and thus also with the level of a weightlifter's performance (Kauhanen et al., 1984). Similarly, Baumann et al. (1988) reported that the discrete GRF peaks during the first and second phase of the pull were highly correlated with total system mass.

While previous studies provide some information about the importance of the GRF with respect to weightlifting performance, they report neither horizontal GRF data nor the angle between the GRF components. However, it is the interactions between the vertical and horizontal components of the GRF, and the angle between them, that afford insight into the dynamic interaction between neuromuscular control strategies, the body's system dynamics, and the external constraints (McNitt-Gray et al., 2013). Further, studying how athletes control the GRF components during a motor task, or regulate them under different conditions provides more complete insight into the coordination patterns during the task (McNitt-Gray et al., 2013). The purpose of this study was to examine how weightlifters control and regulate GRF as they perform the snatch and clean during competition situations.

METHODS: Six skilled weightlifters (body-mass: 106.0±13.2 kg; competition maximum snatch: 98.8±6.3 kg: competition maximum clean and jerk: 126.4±22.9 kg) provided written informed consent approved by the local University's IRB.

Data were collected for each of the three snatch and clean & jerk lift attempts during a sanctioned weighlifting competition. Kinetic data were collected at 1,250 Hz from two force plates that were built into a 2.4 m x 2.4 m weightlifting platform (Kipp et al., 2011). GRF data were filtered with a 4th order low-pass Butterworth filter at a cut-off frequency of 25 Hz. Horizontal and vertical GRF were extracted from both force plates, and the GRF components were summed into a single GRF vector. Horizontal GRF were defined such that positive and negative values were directed away and toward the lifter. As such, the convention for the angle between the GRF components is such that a 0 degree GRF angle indicates a GRF vector that is pointing away from the lifter and a 90 degree GRF angle indicates a GRF vector that points straight up.

Only the first successful lift attempt from each lifter was used for analysis. Time-series data of the GRF components and angle of the GRF vector were time-normalized (i.e., registered) to 100% of the lift phase i.e., time from when the vertical GRF exceeded the system (barbell + lifter) weight to the time the vertical GRF fell below 10 Newtons (Figure 1). Vertical GRF, horizontal GRF, and GRF angle time-series data were then submitted to three statistical parametric mapping (SPM) analyses (Pataky, 2010). Each analysis used a one-way repeated measures ANOVA to compare time-series data of the snatch and clean (De Ridder et al., 2015).

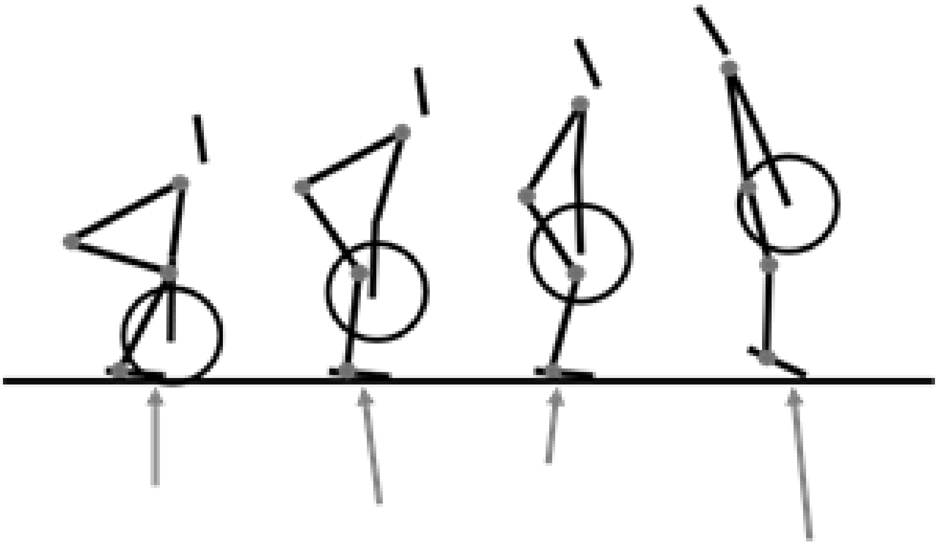

Figure 1: Illustration of the pull-phase analysed (grey lines illustrate the GRF vector).

RESULTS: The SPM analysis indicated a significant difference between the vertical GRF during the snatch and clean between ~0-35% of the pull-phase (Figure 2a). Identically smooth random time-series data would produce a cluster of this breadth with a probability of p = 0.001 (Figure 2d). Post-hoc analysis showed that the vertical GRF of the clean during this phase was significantly greater than of the snatch.

The SPM analysis did not indicate any significant differences between the horizontal GRF of the snatch and clean (Figure 2b).

The SPM analysis indicated a significant difference between the GRF angle of the snatch and clean during the final portion (~95-97%) of the pull-phase (Figure 2c). Identically smooth random time-series data would produce a cluster of this breadth with a probability of p = 0.028 (Figure 2f). Post-hoc analysis showed that the GRF angle of the clean was significantly greater (i.e., directed more toward the lifter) than of the snatch.

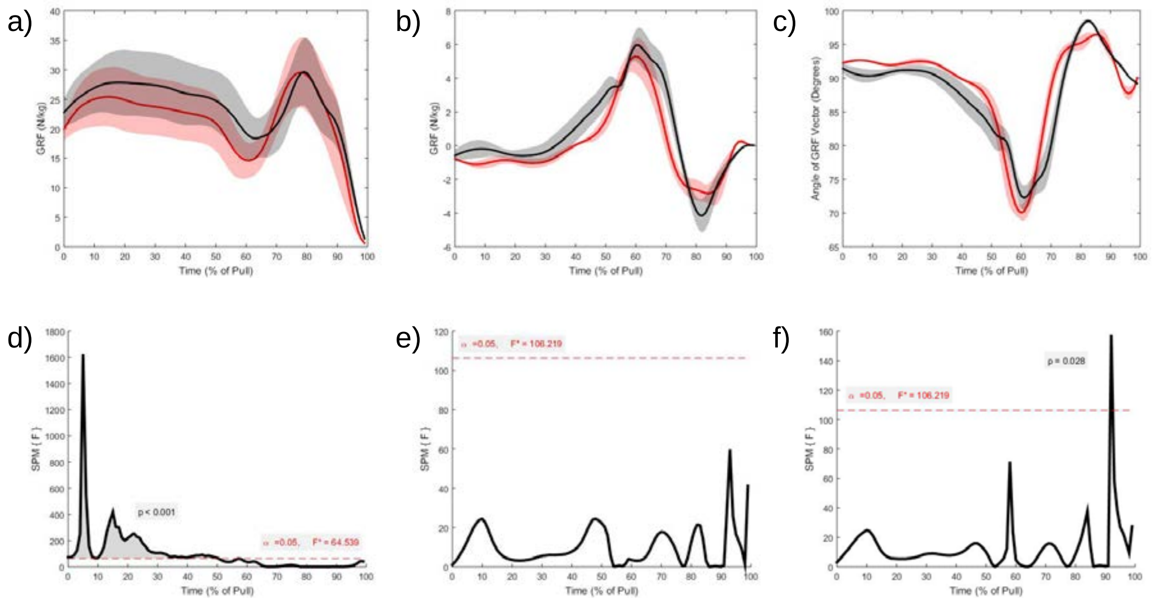

Figure 2: Mean±SD time series (a-c) and SPM (d-f) data for the vertical GRF (a, d), horizontal GRF (b, e), and GRF angle (c, f).

DISCUSSION: The purpose of this study was to determine how weightlifters control and regulate ground reaction forces (GRF) as they perform the snatch and clean during competition situations.

With respect to the control of the GRF, examination of the ensemble average and standard deviation time-series data indicates a very stereotypical pattern for all three variables of both lifts. In addition, the standard deviation of the horizontal GRF and the GRF angle time-series were very low throughout the entire pull-phase of the snatch and clean, which suggests that the horizontal component of the forces that act on the lifter-barbell system at the ground are very similar between lifters. The shared similarity in the control of the horizontal GRF and the GRF angle thus likely indicates that the weightlifters in this study shared similar technical characteristics, such as a forward-backward barbell path or shift in the centre-of-pressure (Garhammer & Taylor, 1984).

With respect to the regulation of the GRF, the results indicate that the horizontal GRF component did not differ between the snatch and the clean during any portion of the pull-phase. The results did, however, indicate a significant difference in the vertical GRF between the snatch and clean during the first 35% of the pull-phase. More specifically, the vertical GRF of the clean was significantly greater than of the snatch. The greater GRF during the first portion of the pull-phase are likely due to the mass difference (~20kg) between the lifts, and likely reflect the greater inertia of the barbell that must be overcome during the beginning of the clean compared to the snatch. This finding is similar to that of others who reported that the discrete peak vertical GRF during the initial portion of the pull-phase of the snatch (Baumann et al. 1988) and the clean (Kauhanen et al., 1984) were positively correlated with the barbell mass.

Although the SPM analysis indicated a significant difference in the GRF angle between the snatch and the clean, this difference occurred over a very small time interval (~2%) of the pull-phase. In addition, the *p*-value associated with this difference (p = 0.028) was also quite a bit larger when compared to the *p*-value associated with the difference in the vertical GRF (p = 0.001). Given that there are currently no methods to calculate effects sizes for SPM analyses it is difficult to establish whether these differences are of practical significance. However, when compared to the *p*-value and cluster breadth of the vertical GRF, the differences in GRF angle would appear to be less pertinent.

The combined lack of difference in horizontal GRF and GRF angle suggests that weightlifters control these variables to the same extent during the execution of both lifts. In contrast, the difference in vertical GRF during the early portion of the pull-phase suggests that weightlifters regulate the normal forces that act on the lifter-barbell system in a manner that scales with the mass difference between the two lifts. Minimal modification in GRF angles may provide an advantage from a sports performance / technique point of view, as it would allow for a simplified coordination patterns that can simply rely on scaling neuromuscular activation (McNitt-Gray et al., 2013).

CONCLUSION: The results highlighted that weightlifters precisely control the horizontal GRF and the GRF angle during the pull-phase of the snatch and clean. In contrast, weightlifters regulated the vertical GRF during the early portion of the pull-phase to accommodate the mass difference between the two lifts. Regulating the vertical GRF component, without changing the GRF angle may provide an advantage in that weightlifters can use similar coordination patterns for both lifts and simply scale muscle activation in correspondence with which lift they are about to perform.

REFERENCES:

Baumann, W., Gross, V., Quade, K., Galbierz, P., & Shwirtz, A. (1988). The snatch technique of world class weightlifters at the 1985 world championships. *International Journal of Sport Biomechanics*, *4*, 68-89.

De Ridder, R., Willems, T., Vanrenterghem, J., Robinson, M. A., Palmans, T., & Roosen, P. (2015). Multi-segment foot landing kinematics in subjects with chronic ankle instability. *Clinical Biomechanics*, *30*, 585-592.

Garhammer, J., & Taylor, L. (1984). Center of pressure movements during weightlifting. In *ISBS-Conference Proceedings Archive* (Vol. 1, No. 1).

Garhammer, J. (1985). Biomechanical profiles of olympic weightlifters. *International Journal of Sport Biomechanics*, *1*, 122-130.

Gourgoulis, V., Aggelousis, N., Mavromatis, G., & Garas, A. (2000). Three-dimensional kinematic analysis of the snatch of elite greek weightlifters. *Journal of Sports Sciences*, *18*, 643-652.

Isaka, T., Okada, J., & Funato, K. (1996). Kinematic analysis on the barbell during the snatch movement of elite Asian weight lifters. *Journal of Applied Biomechanics*, *12*, 508-516.

Kauhanen, H., Hakkinen, K., Komi, P.V. (1984). A biomechanical analysis of the snatch and clean & jerk techniques of Finnish elite and district level weightlifters. *Scandinavian Journal of Sports Sciences, 6*, 47-56.

Kipp, K., & Harris, C. (2015). Patterns of barbell acceleration during the snatch in weightlifting competition. *Journal of Sports Sciences*, *33*, 1467-1471.

Kipp, K., Harris, C. & Sabick, M.B. (2011). Lower extremity biomechanics during weightlifting exercise vary across joint and load. *Journal of Strength and Conditioning Research, 25*, 1229-1234.

Kipp K., Redden J., Sabick M.B. & Harris, C. (2012). Weightlifting performance is related to kinematic and kinetic patterns of the hip and knee joints. *The Journal of Strength & Conditioning Research, 26,* 1838-1844.

McNitt-Gray, J. L., Munaretto, J., Zaferiou, A., Requejo, P. S., & Flashner, H. (2013). Regulation of reaction forces during the golf swing. *Sports Biomechanics*, *12*, 121-131.

Pataky, T. C. (2010). Generalized n-dimensional biomechanical field analysis using statistical parametric mapping. *Journal of Biomechanics*, *43*, 1976-1982.

Stone M.H., O'Bryant, H.,S., Williams, F.E., Johnson, R.L. (1998). Analysis of bar paths during the snatch in elite male weightlifters. *Strength and Conditioning Journal, 20*, 30-38.