EXPLORING THE BIOMECHANICAL CHARACTERISTICS OF THE WEIGHTLIFTING JERK

Jason Lake, Mike Lauder and Rosemary Dyson

University of Chichester, Chichester, West Sussex, UK

The vertical ground reaction force (VGRF) and front foot sagittal plane movement of the weightlifting jerk were recorded from seven weightlifters. Average knee flexion during the dip phase was 58 ± 9 degrees (mean ± SD) at an average angular velocity of 125 ± 16 degrees.s^{-1} exerting a vertical impulse of 138 ± 17.3 Ns. The peak rate of force development was 17.2 ± 4.86 BW.s^{-1}, the VGRF continuing to increase from a propulsion impulse of 113.7 ± 31.2 Ns to a peak drive phase value of 3.5 ± 1.2 BW, extending the knees by 54 ± 9 degrees. The front foot catch phase peak impact VGRF was 3.4 ± 1.2 BW loading at a rate of 285 ±119 BW.s^{-1}. The results indicate that although loading rates are not excessive during the catch phase, careful consideration should be given before introducing the jerk into the strength and conditioning program of the inexperienced.

KEY WORDS: athlete, force, jerk, kinematics, strength.

INTRODUCTION: The clean and jerk allows the greatest loads to be lifted from the ground to arms length overhead during weightlifting competition. Jerk performance is illustrated in Figure 1. At the beginning of the movement the barbell is positioned across the lifters anterior deltoids (Fig 1, a). A rapid countermovement (~13% of body height, Grabe and Widule, 1988) (Fig 1, a-b) contributes to explosive lower limb extension (Fig 1, b-c). The bar is vertically displaced by ~18% of body height (Grabe and Widule, 1988), enabling the lifter to rapidly descend underneath it by splitting the legs fore and aft catching the bar on locked arms overhead (Fig 1, d).

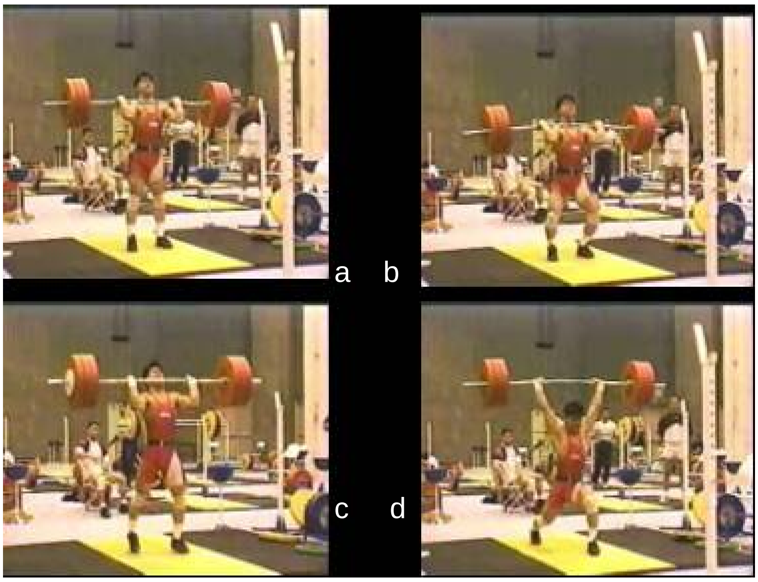

Figure 1. The three main phases of the weightlifting jerk: a-c illustrates the countermovement, encompassing the dip (b-c) and drive phase, and c-d the fore and aft split.

During the jerk relatively large loads are lifted explosively through ranges of motion that are mechanically similar to many sporting movements (Garhammer and Gregor, 1992). For this reason, the jerk is increasingly included in athlete strength and conditioning (S&C) programs (Kawamori and Haff, 2004). Given the recent increase in research interest regarding the kinetic underpinnings of common S&C exercises (Kawamori *et al*., 2005; Tricoli *et al*., 2005) surprisingly little is known about the weightlifting jerk. This lack of knowledge extends to the loading characteristics of the jerk catch phase. With this in mind the aim of the present investigation was to assess biomechanical characteristics of the weightlifting jerk with specific focus given to countermovement and front foot impact force/time parameters.

METHODS: Following a thorough explanation of the experimental aims and procedures, seven recreational weightlifters (male *n*=6, female *n*=1) provided written informed consent to participate in the study. The mean (±SD) height, mass and jerk load characteristics of the subjects were 1.74 ±0.4 m, 81.5 ±14.6 kg, and 65 ±20 kg, respectively. Following a thorough warm up, participants performed progressively heavier single jerks until they reached ~80% of their estimated one repetition maximum (1 RM) with which two single lifts were performed; subjects resting as necessary between lifts (Reiser *et al*., 1996). These lifts were averaged (Kawamori *et al*., 2005) for later analysis. Two Kistler 9281 force platforms (0.4 by 0.6 m, Kistler, Alton, UK) recorded the vertical ground reaction forces (VGRF) of each trial. They were positioned with the 0.6 m edges parallel to each other, the lifter performing the dip and drive phase with both feet on one platform while the front foot landed on the second platform during the catch phase. An Opus technologies personal computer running Bioware 3.21 software recorded the VGRF at a sampling frequency of 200Hz for 3 seconds. The split front foot lower limb movement was recorded using a Peak high-speed video camera (Peak Performance Technologies Inc, Englewood, Colorado) at a sampling frequency of 200 Hz. The camera was positioned on a tripod at a height of 0.8 m, 5 meters from and perpendicular to the lifters sagittal plane. The movement was recorded onto SVHS videotape using Panasonic high-speed AG-5700-E video recorder. Reflective 3-D markers were positioned on the following anatomical landmarks: the greater trochanter of the femur, lateral epicondyle of the knee, and the tip of the lateral malleolus. The centres of these markers were then manually digitised at 200Hz using a Panasonic AG-MD 830 video player and Peak Motus 32 software for Windows 98 and then low pass filtered using a Butterworth filter with a cut off frequency of 6 Hz. These anatomical landmarks defined the thigh and shank segments of the two-segment model that rotated in two dimensions around the knee. A trigger switch was used to synchronise video and force platform data through a synchronization unit (Peak performance Technologies Inc, Englewood, Colorado).
The dip un-weighting, eccentric braking, and concentric propulsion phases were identified by the changes in hip vertical velocity over time (Takarada *et al*., 1997). From this the bilateral drive and unilateral catch phase peak VGRF values and phase durations were determined. The braking and propulsion impulses were calculated as the area under the force/time curve during the eccentric and concentric phases respectively. Peak rate of force development (PRFD) values were calculated from the change in force over a 5 ms sampling period, while the impact-loading rate (LR) was calculated as the change in VGRF to impact peak divided by its duration. From the two-segment model knee angular displacement, average knee angular velocity; hip vertical displacement and peak velocities were calculated according to the methods of Grabe and Widule (1988). Estimates of the peak power output (PPO) were calculated by multiplying the hip vertical velocity by the VGRF. Vertical GRF, PPO and hip vertical displacement values were normalised for each individual's body weight (BW) and height (BH) respectively. All data were exported to Microsoft Excel for analysis and are presented as mean (±SD).

RESULTS AND DISCUSSION: The 80% 1RM jerk loads used during the present investigation were ~76% of the mean subject body weight. A graphical representation of the typical VGRF/ time interaction is shown in Figure 2.

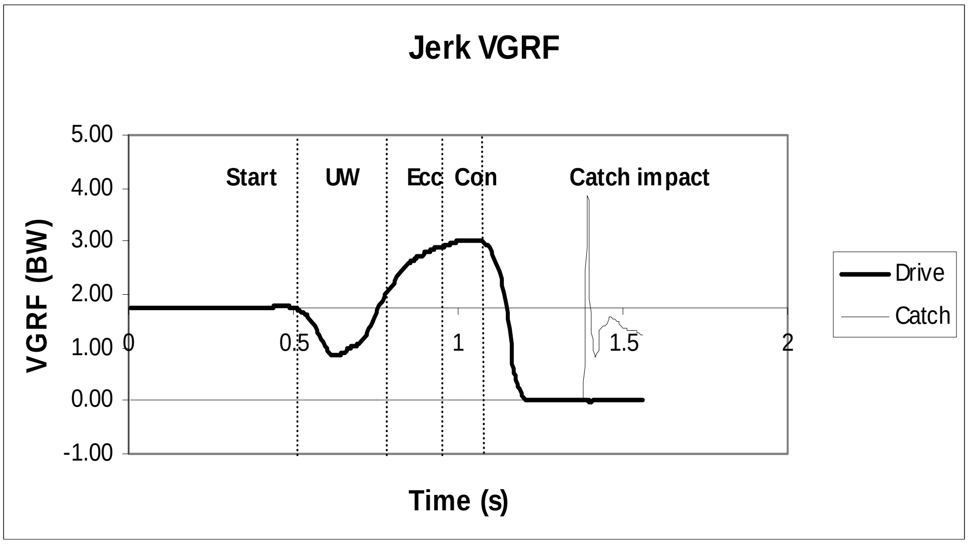

Figure 2. Typical VGRF/time curve of the weightlifting jerk performed with 80% of 1 RM. The dip phase consisted of the un-weighting and eccentric/braking phase, which were referred to as UW and Ecc respectively, while the drive phase was referred to as Con.

Table 1. Mean (±SD) peak values of jerk performance.

Braking impulse (Ns)	**Propulsion impulse (Ns)**	**Peak RFD ($BW.s^{-1}$)**	**Peak propulsion VGRF (BW)**	**Peak catch phase VGRF (BW)**	**Peak catch loading rate ($BW.s^{-1}$)**
138 ±17.3	113.7 ±31.2	17.2 ±4.86	3.5 ±1.2	3.4 ±1.2	285.24 ±118.7

The mean knee flexion for the group was 58 ± 9 degrees at an average angular velocity of 125 ± 16 $degrees.s^{-1}$ during the dip phase. The resultant negative vertical displacement of the hip was retarded by an impulse of 138 ± 17.3 Ns, achieving a final displacement of 11 ± 2% of body height. The knee angular velocity values were similar to those reported by Kauhanen *et al*. (1984), while the hip vertical displacement was within the optimum range outlined by Grabe and Widule (1988). The total dip phase duration was 460±0.08 milliseconds (ms), which was greater than those reported by Kauhanen *et al*. (1984). This may be explained by the UW phase duration of 290 ± 160 ms, which was greater than that reported by Grabe and Widule (1988), while the Eccentric phase duration of 170 ± 30 ms was consistent with their findings. The PRFD of 17.2 ± 4.86 $BW.s^{-1}$ (13.5±2.9 $kN.s^{-1}$) (Table 1) was recorded ~120ms after the negative maximum VGRF value of the UW phase. This was much less than PRFD values recorded for dynamic clean pulls (Haff *et al*., 2000), but similar to those recorded for counter-movement vertical jumping (Wilson *et al*., 1995). During the 70ms Concentric phase (Figure 2) PRFD declined while the VGRF continued to increase, from an average propulsive impulse of 113.7 ± 31.2 Ns, to a peak of 3.5 ± 1.2 BW (Table 1). The mean knee extension was 54 ± 9 degrees at an average angular velocity of 211 ± 43 $degrees.s^{-1}$. The VGRF value was much less than those reported by Kauhanen *et al*. (1984) (4.4 to 5.5BW) for district and elite level lifters, respectively. This may be explained by the higher standard weightlifters and the loads lifted of ~100% 1 RM that were studied by these researchers (*Kauhanen et al*., 1984). Despite this the knee angular displacements (Grabe and Widule, 1988) and angular velocities (Kauhanen *et al*., 1984) were in good agreement with the literature. The estimated relative PPO values of 34 ± 9.5 $W.kg^{-1}$ (3046 ± 472.5 W) recorded during the present investigation were slightly less than those reported by Garhammer (1980). However, it should be considered that not only were the lifters studied by Garhammer (1980) of a much higher standard than the present investigation's, but both the vertical and horizontal work of the bar and the vertical work of the bodies centre of mass was included in his calculations.

Following the maximum knee extension, the knees split so that the lifter could descend underneath the bar to catch it on locked arms overhead. During this phase the front foot impact VGRF reached a peak of 3.4 $\pm$ 1.2 BW over a 20ms period, generating an impact loading rate of 285.3 $\pm$ 118.7 $BW.s^{-1}$ (Table 1). The catch phase data of one subject was excluded from the analysis because his performance was atypical. Despite previous concerns about the injury potential of the jerk (Whittle *et al*., 1988) the loading rates were much less than those previously reported for cricket fast bowling (Hurrion *et al*., 2000).

CONCLUSION: The results of this study provided an insight into the kinetic mechanisms underpinning jerk performance, indicating the large peak power output and peak rate of force development generated during jerk performance. The peak rate of force development was similar to those elicited in vertical jump performance and support the use of the jerk in strength and conditioning programmes.

REFERENCES:

Garhammer, J. (1980) Power production by Olympic weightlifters. Medicine and Science in Sports and Exercise, 12, 54-60.

Garhammer, J. and Gregor, R. (1992). Propulsion Forces as a Function of Intensity for Weightlifting and Vertical Jumping, Journal of Applied Sports Science Research, 6, 129-134.

Grabe, S.A., and Widule, C.J. (1988) Comparative biomechanics of the jerk in Olympic weightlifting. Research Quarterly for Exercise and Sport, 59, 1-8.

Haff, G.G., Kirksey, B., Stone, M.H., Warren, B., Johnson, R.L., Stone, M., O'Bryant, H., and Proulx, C. (2000) The effect of 6 weeks of creatine monohydrate supplementation on dynamic rate of force development. Journal of Strength and Conditioning Research, 14, 326-433.

Hurrion, P.D., Dyson, R., Hale, T. (2000) Simultaneous measurement of back and front foot ground reaction forces during the same delivery stride of the fast-medium bowler. Journal of Sports Sciences, 18, 993-997.

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

Kawamori, N. and Haff, G.G. (2004) The optimal training load for the development of muscular power. Journal of Strength and Conditioning Research, 18, 675-684.

Kawamori, N., Crum, A.J., Blumert, P.A., Kulik, J.R., Childers, J.T., Wood, J.A., Stone, M.H., Haff, G.G. (2005) Influence of different relative intensities on power output during the hang power clean: Identification of the optimal load. Journal of Strength and Conditioning Research, 19, 698-708.

Reiser, R.F., Smith, S.L., Rattan, R. (1996) Science and technology to enhance weightlifting performance: The Olympic program. Strength and Conditioning, August 1996, 43-51.

Takarada, Y., Hirano, Y., Ishige, Y., Ishii, N. (1997) Stretch induced enhancement of mechanical power output in human multi-joint exercise with counter-movement. Journal of Applied Physiology, 83, 1749-1755.

Tricoli, V., Lamas, L., Carnevale, R., Ugrinowithsch, C. (2005) Shot term effect on lower body functional power development: Weightlifting vs. vertical jump training programs. Journal of Strength and Conditioning Research, 19, 433-437.

Whittle, M.W., Sargeant, A.J., and Johns, L. (1988) Computerised analysis of knee moments during weightlifting. In Biomechanics XIB, de Groot, G (Ed), p. 885-888. Free University Press, Amsterdam.

Wilson, G.J., Lyttle, A.D., Ostrowski, K.J., and Murphy, A.J. (1995) Assessing dynamic performance: A comparison of rate of force development tests. Journal of strength and conditioning research, 9, 171-181.