A KINEMATIC ANALYSIS OF THE JERK TECHNIQUE IN OLYMPIC WEIGHTLIFTING

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INTRODUCTION

Weightlifting has been a part of the Olympic Games since 1896. With the elimination of the press after the 1972 Olympic Games in Munich just two lifts have remained: the snatch, and the clean and jerk. Of the two Olympic lifts, the clean and jerk is the lift in which the most weight can be lifted.

In the clean and jerk, the lifter grips the bar approximately shoulder width, pulls it as high as possible in one continuous motion, and then drops under the weight in a squat position while receiving the bar on the shoulders and upper chest. In the second part of the lift, the jerk, the lifter dips and drives the weight up as high as possible, extending the knees and hips and rising up on the toes. The feet are quickly split apart with one forward and one backward while the body drops under the weight which is caught in a split position. To complete the lift, the athlete will recover by bringing the feet in line and shoulder width apart.

There have been a number of studies published on the analysis of the olympic lifts in recent years but most of these have dealt with the pulling phases of the snatch and clean (Garhammer, 1978; Enoka, 1979; Baumann, Gross, Quade, Galbien, & Schwirtz, 1988). Although several studies have shown that jerking the weight overhead seems to be the limiting factor for many lifters when performing a maximum clean and jerk (Sokolov, 1976; Medvedev, Masalgin, Frolov, & Herrera, 1981; Medvedev, Masalgin, Herrera, & Frolov, 1982), few studies have been conducted in which the jerk was analyzed.

In an attempt to determine why there is such a poor success rate in the jerk at competitions, the jerk as it was performed by a highly skilled weight lifter in a competition environment was analyzed. If the source of the problem can be determined, then training methods or techniques can be altered to correct the problem and improve the success rate of the lifting.

METHODS

Three lifts (barbell weights of 170, 186, & 187 kilograms) by Roberto Urrutia (height: 170 cm, weight: 75 kg), a three time world champion and American record holder, videotaped during the 1988 United States National Weightlifting Championships with a 60 Hz camera were analyzed utilizing the Ariel Performance Analysis System (APAS). Of the three lifts selected for analysis, two were successful and one was unsuccessful. Two dimensional coordinates of sixteen body points modeling the human body as a fourteen segment rigid link system were calculated from the video image utilizing the direct linear transformation (DLT) method (Abdel-Aziz & Karara, 1971). In addition, the center points on both ends of the barbell were also digitized. The raw data were digitally smoothed with a cut-off frequency of 7 Hz before being submitted to further analysis.

RESULTS AND DISCUSSION

Results (Tables 1, 2 and 3) are presented and discussed by referring to the following six phases adapted from Frolov & Levshunov (1979): phase 1 - begins the instant the knees begin to flex and ends when the barbell begins to move down; phase 2 - starts the instant the barbell begins to move down and ends when it attains maximum velocity during the half-squat; phase 3 - begins the instant the barbell reaches maximum velocity during the half-squat and lasts until the knee joints reach maximum flexion; phase 4 - begins at the point of maximum knee joint flexion and ends at the point of maximum knee joint extension; phase 5 - begins with the maximum extension in the knee joints and ends at the point where the barbell has reached maximum height. The athlete's feet leave the platform and foot placement is rearranged in the **sagital** plane; and phase 6 - begins at the point of the barbell's maximum height and ends the instant the lifter is fixed in the split position. At the conclusion of this phase the lifter is holding the barbell overhead with elbows fully extended and the lower extremities are in a split-squat position.

According to the literature the most critical part of the jerk is the transition from the dip to the thrust, that is the period from the conclusion of phase 3 to the beginning of phase 4

Table 1. Temporal Results (seconds)

	T1S	T2S	T3U
Phase 1	0.100	0.133	0.116
Phase 2	0.166	0.199	0.176
Phase 3	0.166	0.150	0.133
Phase 4	0.199	0.232	0.183
Phase 5	0.263	0.249	0.213
Phase 6	0.096	0.133	0.133
Total Time	0.993	1.096	0.954
Amortization phase	0.117	0.050	0.134

(Frolov & Levshunov, 1979; Roman & **Shakirzyanov,** 1978). Theoretically, the faster this transition is, the greater the potential energy that can be stored and utilized and, therefore, the greater the forces applied against the platform, which will lead to a greater maximal bar velocity (Frolov & Levshunov, 1979). According to other studies, the duration of the **braking** phase increases as the load of the barbell increases (Roman & Shakirzyanov, 1978). In this study, however, both absolute and relative duration for phase 3 were greatest in **T1S** (lightest load), while relative duration was equal between T2S and T3U (Table 1). This slower **braking** phase in **T1S** did not seem to hinder barbell velocity in phase 4 (Table 2) Although the duration of the breaking phase is of significant importance, it might be that the duration of the amortization phase is more critical. Amortization occurs at the end of phase 3 with the transition from concentric to eccentric contraction in the primary muscles involved. It can be measured by the amount of time the knee joint remains at maximum flexion. The duration of this phase was 0.117, 0.05, and 0.134 seconds respectively for T1S, **T2S,** and **T3U.** It should be expected that **T1S** would have the shortest duration because of the lighter barbell load and also because the maximum descending barbell velocity was less than the other two trials (Table 2). That, however, was not the case.

Compared to the other two trials, trial T2S was characterized by a much deeper dip as shown by the amount of flexion in the knee. hip, and ankle joints (Table 3). This led to increased duration and vertical barbell displacements during the dip and thrust phases (Tables 1 and 2).

Table 2. Bar Displacements (BD) (cm) and Velocities **(m/sec)**

	T1S	T2S	T3U
Greatest Descending Horiz. BD	3.20	3.00	3.4
Net Descending Horiz. BD	**+0.60**	**+3.00**	**+2.60**
Vertical Desc. BD (absolute	16.80	20.90	18.20
Vertical Desc. BD (% of height)	9.90	12.30	10.70
Greatest Ascending Horiz. BD	6.40	3.10	4.10
Net Ascending Horiz. BD .	-5.20	-1.00	**+4.10**
Vertical Desc. BD (absolute)	43.20	36.20	31.20
Vertical Desc. BD (% of height)	25.40	21.30	18.40
Maximum Desc. Bar Velocity	1.02	1.12	1.20
Maximum Ascend. Bar Velocity	2.25	1.78	1.92

Note: + indicates forward **motion**, - indicates backward motion

When evaluating joint angles at phase 6, some substantial differences in values should be noted. These values indicate that as the barbell got progressively heavier and ascending vertical barbell displacement decreased with each successive trial, the lifter compensated by dropping his body into a lower receiving position to accommodate **the** barbell. The right leg is thrust forward during this repositioning of the lower extremities and thus the right knee angle is critical as most of the weight is supported with the forward leg. There was a progressive increase in knee, hip and ankle joint flexion with each trial. This compensation was sufficient in T2S but in T3U the knee joint flexion reached a point of less than 90 degrees which presents an unstable position that most lifters are unable to recover from when utilizing maximum loads (Miller, 1976). **In** fact Roman (1986) suggests the optimal amount of knee flexion at this point should be approximately 120 degrees. This subject was well below that value with 93 and 88 degrees for trials T2S and **T3U,** respectively.

Ideally, the bar should only move in the vertical direction. One of the greatest differences between T2S and T3U and probably the most critical, was the amount of **horizontal** barbell displacement exhibited throughout the movement and especially the substantial forward ascending barbell displacement seen in **T2U,** which relates to its decreased vertical ascending bar displacement (Table 3). A factor that contributed to the lack of vertical bar displacement and greater horizontal bar displacement in T3U was the lack of hip extension at the end of phase 4 (Table 3). The extension **of** the hips during the thrust in the jerk is one of the most critical factors (Miller, 1976). It allows the barbell to be driven to a greater height as well as keeping the barbell trajectory in a vertical pattern (Roman & **Shakirzyanov,** 1978). The fact that the knee joints reached a near fully extended position while the hip joints did not, indicates a greater amount of forward inclination of the upper body during the thrust in T3U which contributed to forward barbell displacement. Also this caused the barbell to leave the shoulders before the lifter had reached a fully extended position decreasing the potential for maximum vertical barbell displacement.

Table 3. Joint Angular Results at Selected Positions (degrees)

	T1S	T2S	T3U
Knee Joint Angle at P1/P2/P3	17611381123	17311261109	17811311117
P4/P6	1671110	160/93	170188
Hip Joint Angle at P1/P2/P3	17811381143	17311261137	17811311137
P4//P6	172/123	175198	166/95
Ankle Joint Angle at P6	110	102 .	90

Note: Joint angles at conclusion of each phase except P1 (beginning)

CONCLUSION

Based on the study's collected data, and the limitations and assumptions of the study, several conclusions were derived. Vertical barbell displacement must be sufficient enough to allow the lifter to fix the barbell overhead. This displacement is closely related to the barbell velocity generated during the thrust phase. There is an inverse relationship between the load of the barbell and barbell velocity. Barbell velocity during the thrust phase is a limiting factor but adequate barbell velocity alone is not indicative of a successful lift. The forces must be applied in the right direction as indicated by the barbell trajectory. In the jerk, the barbell should follow a near vertical path with a slight backward deviation as maximum barbell height is reached. It is also crucial that the greatest possible extension is reached in the hip, knee, and ankle joints at the end of the thrust phase. With a given barbell velocity, the greater the extension is in these joints, the greater the potential for maximum vertical barbell displacement above the initial starting position in the jerk.

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