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Biomechanical Profiles of Olympic Weightlifters

John Garhammer
St. Mary Medical Center, Long Beach, CA

The heaviest successful snatch and clean and jerk for five Gold medalists in weightlifting at the 1984 Olympic Games were analyzed from 16mm film. Bar trajectories all showed that as the barbell was lifted from the platform it moved toward the athlete during the first pull, then away from the athlete and finally toward him again as it began to descend during the catch phase. Bar velocity profiles showed that most lifters decelerated the barbell at the end of the first pull while reorienting their body position for the second pull. Calculated power outputs were large in magnitude and showed considerable similarities for selected phases of the lifts of a given athlete. Power output values for complete snatch and clean pulls typically ranged between 28 and 35 W/Kg of body mass. Higher values were found for subphases of the pulls and for the jerk thrusts. Previously published data on one of the Gold medalists permitted longitudinal comparisons of his lifting technique. High power output capacity was the most distinguishing characteristic of the athletes studied and is likely necessary for successful participation in weightlifting at the elite level.

In weightlifting, as in other sports, accurate information about performance characteristics of the world's best athletes is of great interest for scientific knowledge about how the lifting movements are executed as well as practical issues related to coaching. The vast majority of published biomechanical studies of weightlifting involves data collected in the laboratory or at competitions well below world championship level. The ideal situation would be to obtain data on world-class athletes while they are competing in top physical condition and under maximal competitive pressures. Such is the situation at world championship and Olympic Games competition. However, few competitions at that level have been studied. Ono, Kubota, and Kato (1969) reported selected bar kinematics and body segment orientations for gold medalists at the 1964 Tokyo Olympic Games, while Garhammer (1981) reported selected bar kinematics and power outputs for gold medalists at the 1978 World Weightlifting Championships. The purpose of this report is to contribute additional data on world-class weightlifters competing during the 1984 Summer Olympic Games.

Direct all correspondence to John Garhammer, Biomechanics Laboratory, St. Mary Medical Center, Long Beach, CA 90813.

Methods

High speed 16mm pin-registered cameras were used to obtain research-quality films of selected athletes competing in weightlifting at the 1984 Olympic Games in Los Angeles. Two phase-locked Redlake LoCam cameras provided a forward (anterior) and side (lateral) view of the athletes relative to their starting position. The film plane of the master camera was located approximately 9.5m to the right side of the competition platform with the optical axis of its lens passing approximately 0.5m above the geometric center of the platform surface. The film plane of the subordinate camera was located approximately 19m in front of the competition platform center with its optical axis also passing approximately 0.5m above the platform surface.

In order to obtain a reasonable sample of the most talented weightlifters from countries throughout the world, all lifts in the "A" section of five body-weight divisions, reasonably distributed from lightest to heaviest, were documented on film. These were the 56, 75, 82.5, 100, and 110+ Kg classes. In addition, selected lifts during the "A" section of the 52 Kg division were filmed the first day of the weightlifting competition in order to test the cameras and filming procedures. During this test filming the cameras were set to operate at 100 fps. This camera speed resulted in an undesirable noise level near the competition platform and necessitated more frequent changes of film reels than desired. For these reasons the cameras were set to operate at 50 fps during the filming of the 56 Kg and all subsequent body-weight divisions.

Lifts chosen for analysis included the heaviest successful snatch and clean and jerk made by the gold medal winners in the 56, 75, 82.5, 100, and 100+ Kg divisions. Additional lifts of the 100 Kg division winner were analyzed to permit a comparison of lifts with different weights and to make longitudinal comparisons with published data from his winning performance at the 1978 World Weightlifting Championships.

During each snatch and clean analysis, the path of the bar was registered from the side view film from the time just prior to when the barbell plates left the floor ("lift-off") until just after the bar reached its highest point above the platform surface while the athlete was moving into the squat position to catch it. During each jerk analysis the same procedure was followed from when the athlete began to flex his knees, prior to thrusting the barbell upward, until his feet began to leave the platform surface to "split" and catch the barbell overhead. Film of each lift was digitized using either a Vangard projection head and a Talos digitizing system, or a Lafayette projector and a Numonics digitizing system, interfaced to an Apple IIe computer. Some of the lifts studied were digitized using both systems to check on intersystem consistency. All lifts analyzed were digitized by the author to avoid interoperator variations. No measurements were taken from front view film of the lifts.

Results

Fifteen parameters were determined for snatches and cleans from the position-time data obtained by film digitization. Five parameters were similarly determined for jerks. Values are presented in Table 1 for the heaviest lifts of winners in the 56, 75, 82.5, 100, and 110+ Kg divisions. The following is an explanation of the parameters presented in Table 1:

Table 1

Measured Parameters for Selected Gold Medal Winners in Weightlifting at the 1984 Olympic Games

Athlete/BWT (KG)	LIFT (KG)	TRAJ (CM)	EFF (%)	VEL (CM/S)	T_1 (S)	YMAX (CM)	T_2 (S)	P_1 (W)	P_2 (W)	T_3 (S)	PMAX (W)	T_4 (S)
SW/55.7	1S-120	4, −5, −1	97	—,—,194	.70	98	.94	1770	3190	.16	3004	.38
	3C-147[5]	3,0,6	99	105,95,173	.74	82	.98	1677	3142	.18	3723	.34
	3J-147[5]	—	99	—,—,162	—	—	—	—	2825	.18	4033	—
KR/74.3	2S-150	4,0,6	98	—,—,201	.64	97	.88	2533	4052	.16	4650	.32
	1C-190	4, −4,3	90	124,115,168	.66	81	.88	2600	3877	.14	4732	.30
	1J-190	—	98	—,—,186	—	—	—	—	3804	.22	5782	—
PB/81.6	2S-155	9,3,12	96	133,115,182	.76	102	.98	2423	3689	.18	3778	.30
	3C-200	7,1,8	95	—,—,154	.88	88	1.06	2268	3543	.18	3982	.30
	3J-200	—	99	—,—,157	—	—	—	—	3548	.20	3548	—
RM/97.7	3S-167[5]	4, −6,0	95	135,117,194	.70	106	.94	2920	4714	.16	4852	.38
	3C-217[5]	4, −4,2	94	115,88,165	.76	86	.96	2772	4983	.14	5362	.32
	3J-217[5]	—	99	—,—,173	—	—	—	—	4170	.22	5621	—
DL/138.5	2S-172[5]	7, −11, −5	87	162,107,210	.76	129	1.04	3671	5442	.18	4904	.36
	2C-240	5, −9, −6	93	129,92,173	.86	101	1.06	3360	6120	.14	6255	.36
	2J-240	—	99	—,—,194	—	—	—	—	4321	.32	6953	—

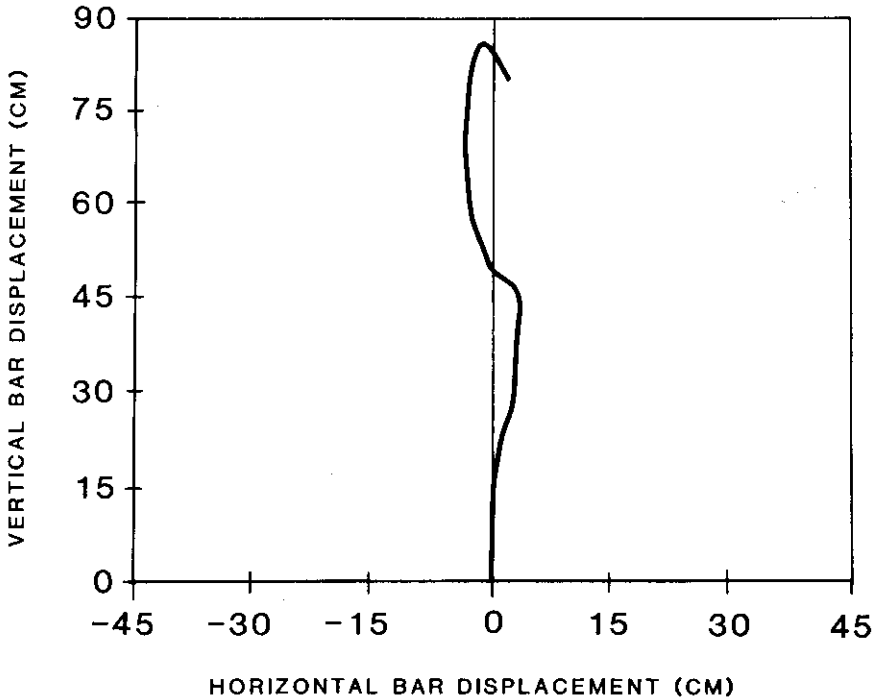

Figure 1 — Bar trajectory for the third attempt clean of RM with 217.5 Kg.

Athlete/Bwt (Kg):

This stands for the initials of the athlete and his body weight in kilograms.

LIFT (Kg):

This column shows the lift analyzed and barbell weight in kilograms. Examples: 1S-120 means first snatch attempt at 120 Kg; 2C-240 means second clean attempt at 240 Kg; and 3J-200 means third jerk attempt at 200 Kg.

TRAJ (CM):

Shown are three key position values relative to the bar's trajectory (see Figure 1). The first number is the maximum movement distance of the bar, during the first pull, away from a vertical reference line drawn through the bar just prior to lift-off. This number was always found to be positive, representing movement of the bar toward the lifter. The second number is the maximum distance of the bar from the vertical reference line during the second pull. This number was often found to be negative, indicating movement of the bar away from the lifter to the opposite side of the vertical reference line during the second pull. See for example RM's lift in Figure 1. The third number is the distance of the bar from the vertical reference line just after it began to descend from maximum height. This number was usually found to be positive, meaning that the bar was on the lifter's side of the vertical reference line.

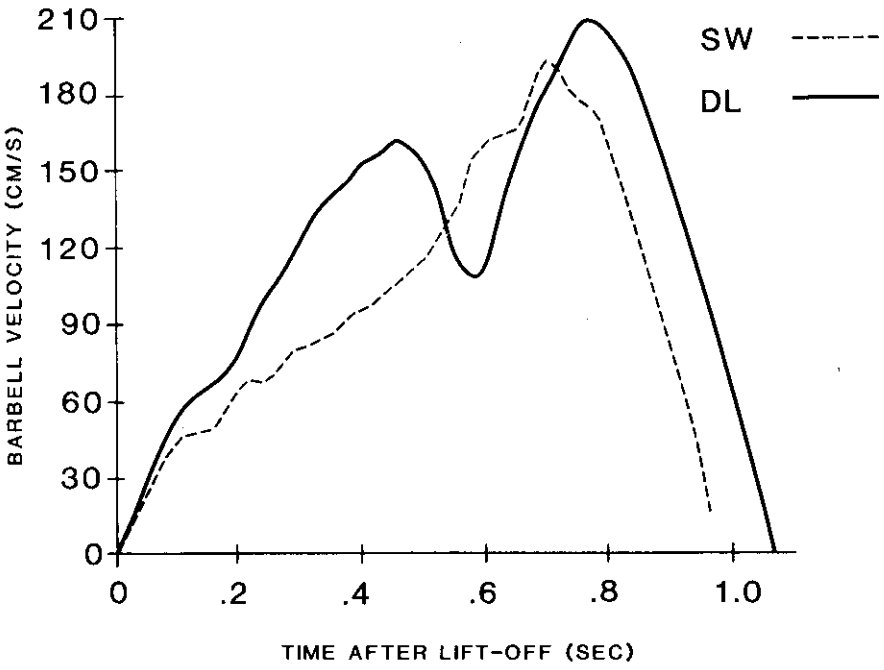

Figure 2 — Barbell velocities for the first attempt snatch of SW with 120 Kg and the second attempt snatch of DL with 172.5 Kg.

EFF (%):

This represents the efficiency of the pull or jerk drive, or the percent of total work done in lifting the weight resulting in vertical lift (as opposed to horizontal motion).

VEL (CM/S):

This shows the vertical velocity of the bar at three key positions during a snatch or clean pull. The first number is the peak velocity attained during the first pull (see Figure 2). The second number is the bar velocity after rebending of the knees, just as the second pull was about to begin. The third number is the maximum velocity reached at the end of the second pull. Only the peak velocity attained during the jerk thrust is listed. If only one velocity value is listed for a snatch or clean pull it means that no distinct maximum and minimum value was found prior to the final maximum value.

T_1 (S):

This column represents the time from lift-off until maximum bar velocity was reached.

YMAX (CM):

This shows the maximum height the bar reached during a snatch or clean pull.

Table 2

Measured Parameters of One Athlete (RM) from Two Different Weightlifting Competitions

Meet	BWT (KG)	LIFT (KG)	TRAJ (CM)	EFF (%)	VEL (CM/S)	T_1 (S)	YMAX (CM)	T_2 (S)	P_1 (W)	P_2 (W)	T_3 (S)	T_4 (S)
78WC	89.7	3S-162[5]	7,0,8	95	138,132,220	.66	112	.94	3139	4976	.16	—
		1C-210	7,1,7	95	122,106,179	.72	88	.94	2892	4538	.16	—
		2C-215	7, – 1,7	95	119,92,172	.76	86	.94	2837	4700	.16	—
		2J-215	—	99	202	—	—	—	—	5072	.22	—
84OG	97.7	1S-162[5]	4, – 6, – 3	98	140,128,203	.70	109	.94	2862	4742	.16	.38
		3S-167[5]	4, – 6,0	95	135,117,194	.70	106	.94	2920	4714	.16	.38
		1C-210	4, – 2,2	95	125,104,178	.74	90	.96	2897	4839	.14	.32
		3C-217[5]	4, – 4,2	94	115,88,165	.76	86	.96	2772	4983	.14	.32
		1J-210	—	99	177	—	—	—	—	4125	.22	—
		3J-217[5]	—	99	173	—	—	—	—	4170	.22	—

78WC = 1978 World Weightlifting Championships, Gettysburg, Pennsylvania, USA.
84OG = 1984 Olympic Games, Los Angeles, California, USA.

T_2 (S):

This shows the time from lift-off until the bar reached maximum height.

P_1 (W):

This stands for the average power output in watts to lift the barbell and body weight during the entire pull, from lift-off until max velocity was reached. Power was the work done in lifting divided by the total time of the lifting movement. The work done to move the barbell vertically and horizontally was included in this calculation.

P_2 (W):

This column shows the average power output in watts to lift the barbell and body weight during the second pull or jerk drive. Only the work done to lift body weight and move the barbell vertically was included in this calculation.

T_3 (S):

This represents the duration of the second pull or jerk drive, and the time value used to calculate P_2.

PMAX (W):

This is the maximum "instantaneous" power output (0.02 s time interval) during the second pull or jerk drive. Neither the lifting of body weight nor work to move the barbell horizontally was included in its calculation, and that is why some P_2 values are greater than PMAX.

T_4 (S):

This shows the time in seconds to "move under the bar." It was measured as the time from maximum vertical bar velocity at the end of the second pull until the lifter's elbow rotated to a position directly below the bar while moving under the barbell to catch it.

Most of the parameters defined for Table 1 are also listed in Table 2, which gives values for four of RM's five successful lifts at the 1984 Olympic Games and three of his four successful lifts at the 1978 World Championships. Additional information regarding calculation procedures may be found in Garhammer (1979) and Garhammer (1980a)

Discussion

The barbell trajectories for the heaviest successful snatch and clean of these elite weightlifters were similar in one respect. All showed initial movement of the bar toward the lifter during the first pull, followed by movement away from the lifter, and finally toward the lifter again as it began to descend while the lifter moved under it for the catch. The magnitude of initial bar movement toward the lifter ranged from 3 to 9 cm, while subsequent movement away from the lifter ranged from 3 (3 to 0 cm for SW) to 18 cm (7 to −11 for DL). The final movement toward the lifter during the catch ranged from 3 (−9 to −6 for DL) to 9 cm (3 to 12 for PB). The trajectory shown in Figure 1 approximates

that which some experts consider optimal (Vorobyev, 1978); however, relative body segment lengths and other leverage factors, such as muscle attachment points, will influence optimum trajectory for a given athlete. Lifters with a large negative value for the third trajectory position usually jump forward to catch the barbell, as was noted in the film of DL. A large positive value for the third trajectory position usually results in the lifter jumping backward to catch the barbell, as was noted in the film of PB.

Efficiency of the snatch and clean pulls ranged from 87 to 99%. Calculation of this parameter depended not only on the range of horizontal motion but also on the horizontal accelerations associated with the motion. Efficiency of the jerk thrusts were all 98 or 99%, indicating minimal horizontal motion. Maximum barbell velocities during the pull were about 10 to 20% higher for the snatch compared to the clean. Maximum velocities during the jerk were between the maximum snatch and clean velocities for each lifter, except for SW whose jerk velocity was lower than his clean velocity. Magnitudes of the maximum velocity values were similar to those previously reported for the 1978 World Weightlifting Championships (Garhammer, 1981). Most of the lifters were found to have an initial maximum in pull velocity followed by a relative minimum before the absolute maximum. This can be seen in Figure 2 for the snatch lift of DL. Such a velocity pattern is due to rebending of the knees and shifting of the torso to a more vertical position after the first pull and prior to the start of the second pull. During this transition the vertical force on the barbell decreases, resulting in a decrease of bar velocity. The smoother and faster the transition, the smaller the decrement in velocity.

Enoka (1979) has presented theoretical reasons for using this "double knee bend" style of lifting technique in terms of leverages and reutilization of the knee extensor muscles in their greatest force producing range of motion. If the increase in pull velocity showed no distinct relative minimum, as for SW's snatch lift in Figure 2, then only the final maximum value was listed in Table 1. Jerks always had a steady increase in velocity to maximum. The time interval from lift-off until maximum velocity was reached differed somewhat for the snatch and clean pull of a given athlete. The greatest difference was .12 seconds for PB. Greater overall similarities in these two time values were expected for each lifter based on previous data (Garhammer, 1981). The present data indicated that some elite athletes can compete successfully and have different timing characteristics for their snatch compared to their clean pull. The maximum height to which the bar was pulled for a snatch was greater for each lifter than for his clean. The time interval from lift-off until maximum height was reached in each lift was similar for a given athlete and is in agreement with previous findings (Garhammer, 1981).

Average power outputs of a given lifter during his snatch and clean pull were similar, differing by less than 10%. Average power outputs of a given lifter were also similar for his snatch and clean second pull and jerk thrust. These values differed more as the time duration (T_3) differences for these movements increased. Similarities in power output values have been previously noted in the literature (Garhammer, 1980a, 1980b, 1981). The maximum power outputs (PMAX) calculated during a .02-second interval during the pull or jerk motions included only vertical work done in lifting the bar, not horizontal work or work done in lifting body weight. These additional work terms could raise the total value by more than 20%. Thus, all three power parameters presented in Table 1 indicate that athletes trained in Olympic style weightlifting have an extremely high capacity to develop power, which is necessary for success in the sport. The final column of Table 1 lists the time required from the instant that maximum bar velocity was reached until the athlete moved his body under the barbell to catch it. For a given lifter this value was

similar for his snatch and clean. These values were all in the range of .30 to .38 seconds, indicating a very rapid movement of the body from the top pull position into the catch position.

Table 2 compares several successful lifts of RM from both the 1978 World Weightlifting Championships and the 1984 Olympic Games. Many similarities can be noted, but overall the data suggest that this athlete was in better physical condition in 1978 when he lifted almost identical weights while being 8 Kg lighter in body mass. Note that in either competition, when a heavier snatch or clean is compared to a lighter one, the maximum bar velocity and height as well as the power output values are almost always lower for the heavier weight. This inverse relationship has previously been noted for elite weightlifters and powerlifters (Garhammer & McLaughlin, 1980).

Summary

This paper presented selected kinematic variables and power output values associated with the winning lifts in five bodyweight divisions during the weightlifting competition at the 1984 Olympic Games. A high degree of consistency was generally noted in time duration and power output variables for the snatch and clean of a given athlete. This was in agreement with previously published data on world-champion weightlifters (Garhammer, 1981). Power outputs per unit of body mass ranged from 28 to 35 W/Kg (excluding the heaviest lifter) for complete snatch and clean pulls. This range was slightly below that previously found for world-champion lifters (Garhammer, 1981), but the weights lifted in the 1984 Olympics were lower (except for the 56 Kg division) than in the comparison competition (1978 World Championships). High power output capacity was the most obvious characteristic of the athletes studied. Through additional analyses of lifting films taken at the 1984 Olympic Games, and future world-level competitions, a clearer biomechanical profile of elite weightlifters should be possible. Of particular interest is the trend of biomechanical parameter changes between first and second as well as second and third attempt lifts in a given competition.

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