

## A Comparison of Maximal Power Outputs Between Elite Male and Female Weightlifters in Competition

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Films taken at the first Women's World Weightlifting Championship were analyzed to determine the average power output during the total pulling phase, and the second pull phase, for the heaviest successful snatch and clean lift of gold medalists in each of nine body-weight divisions. Comparisons were made with previously published data on power output by male lifters in World and Olympic competition. Average relative power output values were one and a half to two times greater for both men and women when only the second pull phase of each lift was analyzed. Results show that women can generate higher short-term power outputs than previously documented, but lower than for men in absolute values and relative to body mass. Male/female comparisons in other high power sport events and basic strength measures are discussed. The high power outputs suggest the value of including the types of lifts analyzed in training programs to improve short-term power output.

Values for the mechanical power output generated during the execution of a variety of weightlifting exercises have been published. Those determined for Olympic style lifting movements were highest in magnitude and have been compared to the values for other types of lifts in an extensive review article by Garhammer (1989a). For example, elite heavyweight competitive lifters had power outputs during 1-RM lifts of 415 W in the bench press, 900 W in the squat, and 3,413 W in the clean. The power output magnitudes for Olympic style lifting were found to be greater than those reported in the literature for any other short-term (less than 2 seconds) activity begun from rest (Garhammer, 1980b).<sup>1</sup> However, no data have been found on the power output generated by women during execution of the Olympic lifts, nor were such data available for women performing other weightlifting exercises or other short-term explosive athletic activities.

Since analyses of Olympic lifting movements have resulted in the highest reported power outputs for men, corresponding data for women should provide insight as to what their maximal power output capabilities might be. In addition, there are numerous bodyweight divisions in Olympic style weightlifting, thus analysis of films taken during competition can provide data for subjects of different

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sizes, permitting comparison of actual power output per unit body mass with theoretical limits. The purpose of this research, then, was to determine the power output generated by women athletes who competed in and won the nine bodyweight divisions contested at the first Women's World Weightlifting Championships in Daytona Beach, Florida, in 1987.

## Methods

Films (16mm, Kodak 121-8841, 400 ASA) were taken using a battery powered Redlake LoCam camera at 50 fps during the first (1987) Women's World Weightlifting (WL) Championship. The leveled camera was placed 15 m to the right side (as seen from the audience) of the competitive platform with the optical axis passing approximately 0.6 m above the geometric center of the 4m  $\times$  4m platform. Internal timing lights set at 100 Hz were used to verify film speed. The films were digitized using a Graf Pen (GP6-40) sonic digitizer interfaced to an Apple IIe computer; film was rear projected using an L-F Inc. projector (224A). Raw coordinates of the end of the barbell were smoothed using a five-point moving arc technique, and velocity and acceleration (by repeat application of the technique) were determined from the slope of the arcs (Wylie, 1966). Required points on the body (ankle, knee, hip, etc.) were digitized to determine the location of the body's center of mass.

Power output values for the total pulling phase (barbell lift-off to maximum vertical barbell velocity), and the second pull phase (bar above knees to maximum vertical barbell velocity), of the heaviest successful snatch and clean lift of gold medalists in each of nine bodyweight divisions (44 to 82.5 + Kg) were calculated as previously described (Garhammer, 1979, 1980a). These calculations included vertical and horizontal work done in lifting the barbell, as well as vertical work done in raising the body's center of mass. Power outputs for two jerk lifts were also determined, as in Garhammer (1980a), and are discussed below. Comparisons were made with previously published data (calculated by the same methods) on power output by male lifters in World (Garhammer, 1981) and Olympic competitions (Garhammer, 1985).

## Results

Absolute power output values for the heaviest successful lifts made by the world champion female weightlifters are listed in Table 1, along with selected kinematic parameters. The total pull phase power values (P1) increase fairly steadily from about 1,000 W in the lightest bodyweight division to almost 2,000 W in the 82.5 Kg division. When only the second pull phase of the entire pulling movement was considered, the values ranged from about 1,700 W to almost 3,700 W. Data for two cleans are missing due to irregular camera speed at the beginning of these lifts.

Equivalent data for male weightlifters (52 to 110 + Kg) from the 1978 World Championships and 1984 Olympic Games have been published (Garhammer, 1981, 1985). Figures 1 and 2 compare the absolute power outputs for complete pulls in the snatch and clean between men and women. Figure 3 shows, for both sexes, the consistency of each group in power output per unit body mass (relative power) for snatch and clean pulls, for second pulls in the snatch and clean, and for the

Table 1

## Selected Bar Kinematics and Power Outputs for Division Winners at the 1st Women's World Weightlifting Championships

Lifter/BWT (Kg)	Lift (Kg)	Vmax (cm/s)	T1 (s)	Ymax (cm)	T2 (s)	P1 (W)	P2 (W)	T3 (s)
C.J./43.90	3S-70.0 1C-75.0	207 -	0.78 -	93 -	0.98 -	1031 -	1913 -	0.20 -
H.X./47.15	3S-75.0 2C-95.0	199 148	0.74 0.86	96 76	0.96 1.04	1118 934	1919 1680	0.22 0.20
Y.Z./51.70	2S-67.5 2C-90.0	199 169	0.76 0.82	103 85	1.00 1.06	1101 1063	1732 1945	0.24 0.18
C.A./55.65	3S-75.0 1C-85.0	194 -	0.84 -	104 -	1.10 -	1099 -	1907 -	0.24 -
Z.X./59.65	2S-75.0 3C-105.0	221 164	0.66 0.76	101 78	0.92 0.92	1423 1281	2510 2340	0.18 0.14
G.L./64.35	1S-77.5 2C-102.5	196 148	0.70 0.82	107 84	0.94 0.98	1509 1320	3051 2416	0.10 0.14
L.H./74.25	3S-90.0 2C-120.0	215 167	0.72 0.74	110 88	0.96 0.92	1753 1769	2967 2669	0.20 0.18
K.M./81.80	3S-95.0 3C-125.0	228 169	0.76 0.80	132 102	1.04 1.00	1932 1852	3671 3691	0.14 0.12
H.C./82.6	2S-90.0 3C-120.0	198 148	0.76 0.76	102 77	1.00 0.92	1633 1518	2847 3012	0.20 0.12

1S: First attempt snatch lift, etc; 2C: second attempt clean lift, etc; T1: Time from bar lift-off until Vmax is reached (used to calculate P1); T2: Time from bar lift-off until Ymax is reached; T3: Duration of second pull (used to calculate P2); Vmax: Max. vertical bar velocity; Ymax: Max. bar height; P1: Power output during entire pulling phase of lift; P2: Power output during second pull phase of lift.

## SNATCH PULL POWER OUTPUT VALUES

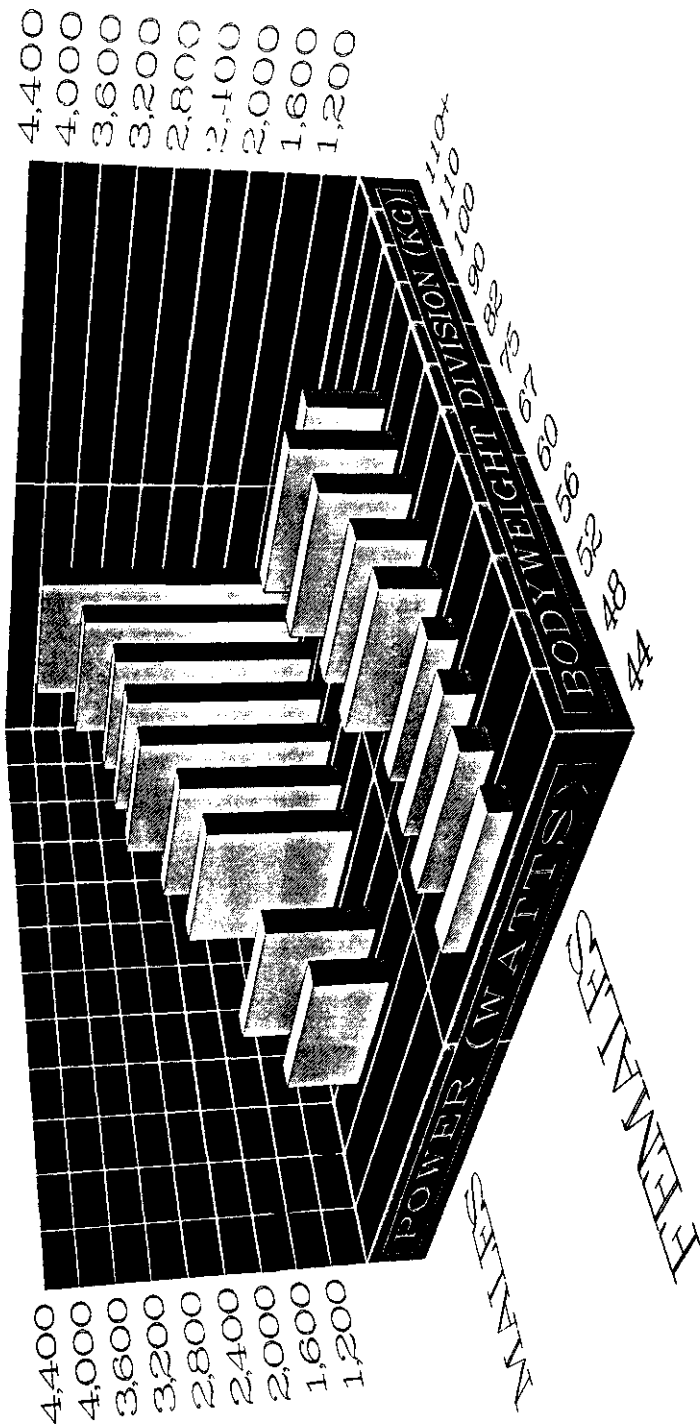


Figure 1 — Absolute power output values for male (1978) and female (1987) athletes during the total pulling phase of snatch lifts.

CLEAN PULL POWER OUTPUT VALUES

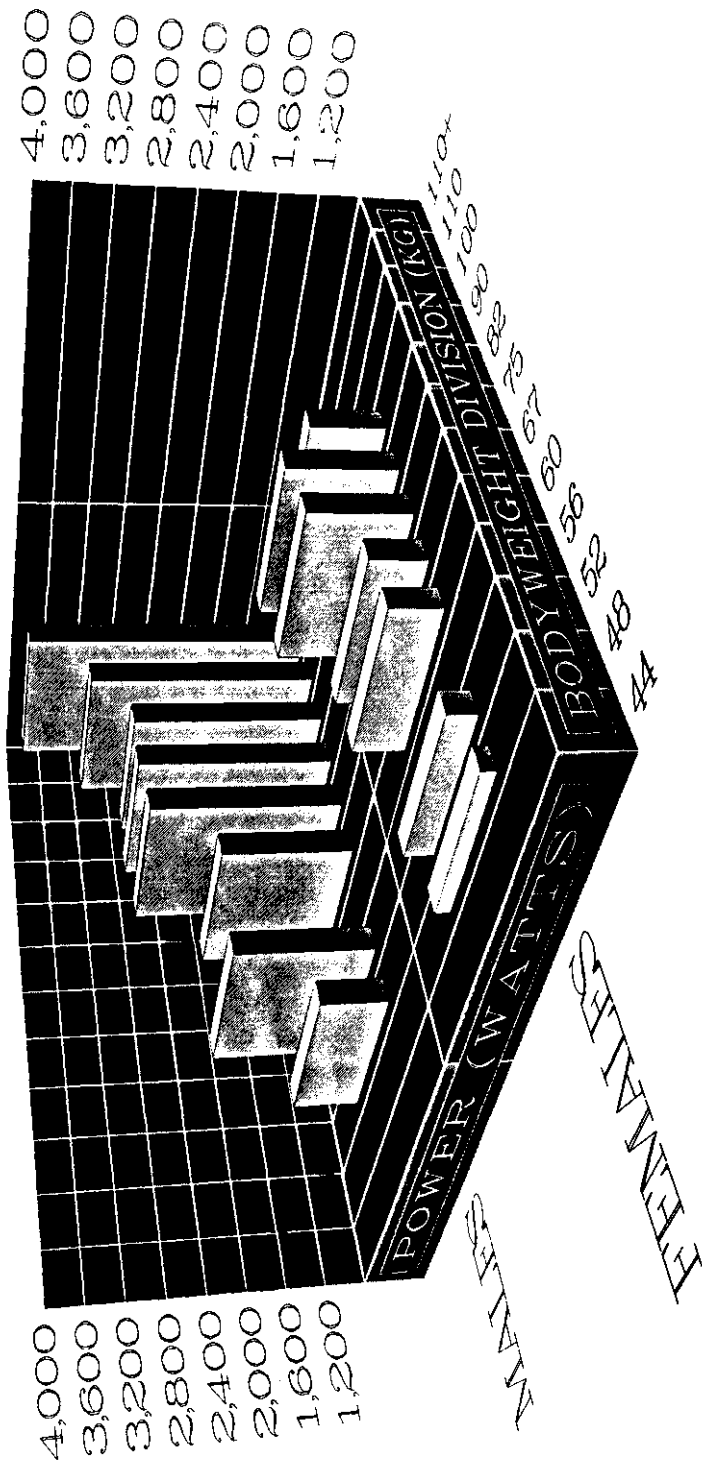
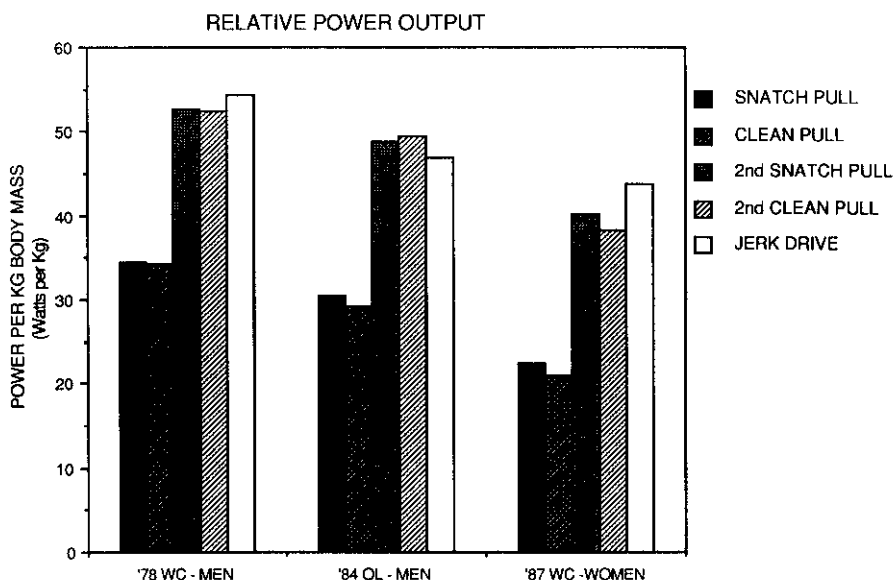


Figure 2 — Absolute power output values for male (1978) and female (1987) athletes during the total pulling phase of clean lifts.



**Figure 3 — Group average relative power output values for various lifting movements for men at the 1978 World Championships and 1984 Olympic Games, and for women at the 1987 World Championships.**

jerk. The men's values from the 1984 Olympics are lower due to the absence of the Russian and Bulgarian teams. Bar trajectory data and a comparison with male lifters' bar trajectories have been presented elsewhere (Garhammer, 1989b, 1990).

### Discussion

For the entire pulling phase of snatch lifts, the women lifters' average relative power output was  $22.5 \pm 1.7$  W/Kg. For men at the 1978 World Championship, the group average relative power output for snatch lifts was  $34.4 \pm 2.5$  W/Kg, the women's value being 65.4% as great. Corresponding values for the entire pulling phase of clean lifts were  $21.0 \pm 1.8$  W/Kg and  $34.2 \pm 3.6$  W/Kg, the women's value being 61.4% that of the men. The small standard deviations indicate considerable consistency for both men and women (over a wide bodyweight range) in power output capacity per unit body mass during a short-duration explosive physical activity.

When only the second pull phase of the entire pulling movement was analyzed, the power output values were much higher. In the snatch lift, the group average relative values for women and men were  $40.1 \pm 5.0$  W/Kg and  $52.7 \pm 4.5$  W/Kg, respectively, the women's value being 76.1% as great as the men's value. The corresponding values for the clean lift were  $38.2 \pm 3.3$  W/Kg and  $52.5 \pm 8.9$  W/Kg, the women's value being 72.8% that of the men. These values again show considerable consistency in each group for power output capacity per unit body mass.

The final phase of the clean and jerk lift requires the barbell to be jerked from the shoulders to arm's length overhead. This movement requires a powerful upward thrusting or jumping action from the leg and hip region of the body. This is very similar to the requirements of the second pull phase of the snatch and clean pull. These similarities were originally pointed out by Garhammer (1980a). Similarities between the thrust force patterns for snatch lifts and vertical jumps have also been documented (Garhammer & Gregor, 1979), as have other kinetic similarities between vertical jumps and clean second pulls (Burkhardt & Garhammer, 1988). Power output values for the jerk have previously been shown to compare closely in magnitude to those of snatch and clean second pulls for male lifters (Garhammer, 1980a, 1981, 1985). Jerk power output values for the women were difficult to determine because the bar began to move out of the camera's field of view as it passed above the athlete's head during the jerk lift. This power calculation was made with confidence, however, for two of the smaller athletes (H.X. and Y.Z.). Figure 3 shows that the average relative power output for these two women in the jerk compares well in magnitude to the women's average relative power output values for snatch and clean second pulls, as was the case for the previously published men's data (also shown in Figure 3).

Wilkie (1960) and McGilvery (1973), based on physiological arguments, estimated the maximal human power output capacity for a short burst of activity to be 54.9 and 64.3 W/Kg, respectively. The relative power outputs for men during the second pull of snatch and clean lifts and jerk thrusts averaged only slightly less than these theoretical maximums. Why the corresponding values for women were only about 75% as great as the men's values is unknown. Skeletal leverages (mechanical advantage) coupling muscle forces to "outside" resistance is unlikely to account for such large differences since men and women in the same bodyweight divisions are of similar body segment size.

Since leg and hip musculature is of primary importance in the lifts being evaluated, it is interesting to consider related male/female comparisons. In the sport of powerlifting, women average 70% as much weight as men in the squat when the current world records are compared for bodyweight divisions in which both men and women compete. In an ergonomically oriented review of the literature, Laubach (1976) found that women average 71.9% the strength of men in static lower extremity strength tests, and 69% the dynamic lifting capacity of men for a lifting task from floor to knuckle level (similar to the initial pulling motion of the clean lift). The women lifters in the study averaged about 63% of the power output of men when the total snatch and clean pulls were compared. The first phase of the total pull is relatively slow and can be considered strength oriented, while the second pull is faster and can be considered more power oriented.

The above data taken as a whole seem to indicate that women compare less favorably to men in slower strength-oriented lower extremity activities than in faster power-oriented lower extremity activities. Since power output in vertical jumps seems comparable to that generated in the second pull for snatches and cleans (Garhammer & Stone, 1990), it is interesting to note that the world record for women in both the high jump and long jump is about 85% that of men. No comparable power outputs for these jumps are available, but considering the lighter average body weight of women jumpers, power output estimates (for equal takeoff thrust times) for women are about 72% those of men (85% jump height  $\times$  85%

as great in body weight). Consistent comparisons of this type challenge sport biomechanists and exercise physiologists for theoretical explanations.

The results of this research show that women can generate higher short-term power outputs than previously documented, but not as much as men in absolute values or relative to body mass. It should be noted that the lifts analyzed here were maximal (one repetition max, or 1 RM). Previous research has documented that power outputs increase as the weight lifted is decreased from maximum (Garhammer, 1985; Garhammer & McLaughlin, 1980). Thus the maximal capabilities of women are likely to be slightly higher than reported in Table 1 and Figure 3.

Athlete H.X. clean and jerked 95 Kg at a body mass of 47.15 Kg. This was the first official double bodyweight clean and jerk for a woman. Note in Table 1 that the two-lift total (3S+2C) of H.X. was not exceeded until Z.X., who was three bodyweight divisions heavier. In addition to the outstanding lifts of H.X., it should be noted that only H.X., L.H., and H.C. repeated as winners in the 1988 and 1989 Women's World Championships. Thus the current values for these three women athletes are of particular reference value.

Lack of as steady an increase in absolute power output with bodyweight division for women as for men (e.g., see Figure 1) was likely related to the fact that weightlifting was a new international sport for women in 1987. More time will be needed to recruit and develop the most gifted female athletes for this sport. This hypothesis is supported by the large increases in winning lifts for several bodyweight divisions at the 1988 and 1989 Championships compared to the 1987 results. The large magnitudes of power output document female capabilities and suggest the value, relative to specificity of training, of the types of lifts analyzed here in training programs to improve short-term power output.

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<sup>1</sup>The author has some data showing that power outputs generated during the standing vertical jump and selected phases of the shot put are similar in magnitude to those generated during comparable phases of Olympic lifting movements (e.g., see Garhammer & Stone, 1990).