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Power production by Olympic weightlifters

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ABSTRACT

GARHAMMER, JOHN. Power production by Olympic weightlifters. *Med. Sci. Sports Exercise.* Vol. 12, No. 1, pp. 54-60, 1980. A new procedure was developed for calculating power production during Olympic lifting movements and comparisons were made with a method previously used. The power output of seven superior lifters was determined during selected phases of the snatch, clean, and jerk, from films taken at the 1975 U.S. National Championships. The values obtained depended on the following variables: vertical change in the bar's mechanical energy from the beginning of a force exertion phase until maximum vertical bar velocity was achieved; work done by the athlete in producing horizontal bar movement; and work done in raising the body's center of gravity. Results showed the expected increase in power with increased bodyweight for a given movement. Values for the jerk drive ranged from 2140 watts in the 56 kg class to 4786 watts for a 110 kg lifter. Heavier lifters exceeded published maximal estimates for human power output during brief exertions. More significant was the high degree of consistency in the rate of work done by any given lifter in movements which were very similar with respect to joint action, but competitively had very different objectives. The procedure should prove useful in detecting problems in lifting movements that result in power outputs which are low relative to those measured for biomechanically equivalent exertions.

WEIGHTLIFTING, WORK AND POWER OUTPUT IN LIFTING, BIOMECHANICS

The kinetic energy that can be imparted to the body, or to an implement, in a short time period is often of prime importance in athletics. The actual work done by an athlete during the short explosive period of propulsion is usually manifested in an increase in both kinetic and potential energy of the system of interest. Thus, the power output or work done per unit of time by an athlete can be used as a measure of performance level.

Wilkie (9) has discussed human power output in terms of maximal values that the human body can produce during exertions of different durations. He concluded that usable external power output of the body is limited to less than 6 horsepower (4476 watts) in single movements of duration less than one second.

Power output during weightlifting was estimated by Fletcher et al. (2) for a "clean" movement, where the barbell is lifted from the floor to the shoulders (Figure 2a-e). The value obtained was two horsepower (1492 watts) during a 0.6 second exertion.

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In 1975 Nelson and Burdett (7) filmed some of the world's top lifters at an international competition. Their analysis methods were more sophisticated than Fletcher's and indicated that a given lifter produces similar power output values in the snatch lift (Figure 1a-e) and clean phase of the clean and jerk lift. The actual values increased from about 1300 watts in the 52 kilogram weight class to almost 3000 watts in the unlimited class.

During the snatch lift, where the bar must be lifted from the floor to arm's length overhead in one motion, an athlete performs most of the mechanical work of lifting the barbell and his center of mass by the time the bar has reached a position slightly above waist height. At this instant his body is fully extended and supported on the balls of the feet, the bar has reached its maximum velocity, and the force applied to the bar has decreased to almost zero (Figure 1d). This statement is of prime importance and its meaning must be emphasized. From the "top pull" position described above a lifter begins to move his body under the bar to catch and support it. This means that the body center of mass has been lifted to maximum elevation and has a velocity of essentially zero. At the same time the bar has not reached maximum elevation but has reached maximum velocity. Force plate (3,8) and bar acceleration data (1,4) support the contention that force applied to the bar, immediately following the top pull position, falls rapidly to low magnitudes for both the snatch and clean pull. For a given lifter the elevation and maximum velocity of the bar are lower at the top pull position of the clean compared to that of the snatch (compare Figures 2d and 1d). In the next few tenths of a second the bar reaches maximum elevation with little additional work being done on it due to small applied forces. If the power output of a lifter is calculated for the snatch or clean by considering the work done to lift the barbell vertically to its maximum elevation, and the time required to reach this height, then the value obtained will be conservative since this amount of work was essentially performed by the time the bar had attained maximum velocity. This conservative method was used in previous determinations of power output by weightlifters (2,7).

The purpose of this paper is twofold: 1) To support the contention that methods previously used to calculate power output by Olympic weightlifters are conservative and not a sensitive measure of performance level and 2) To

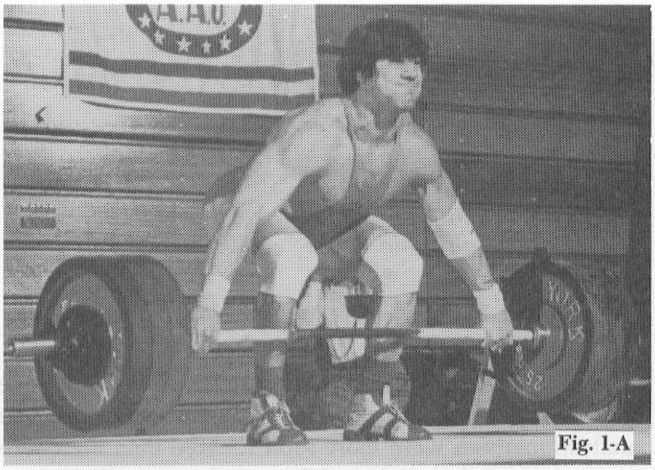


Fig. 1-A

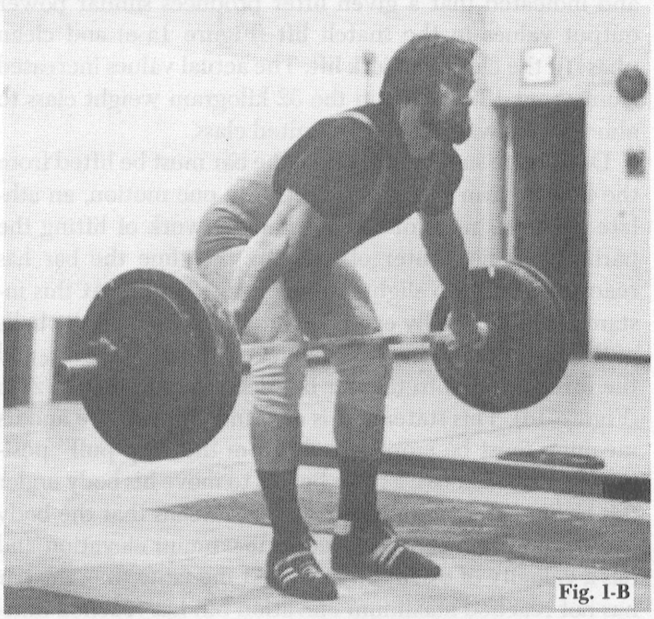


Fig. 1-B

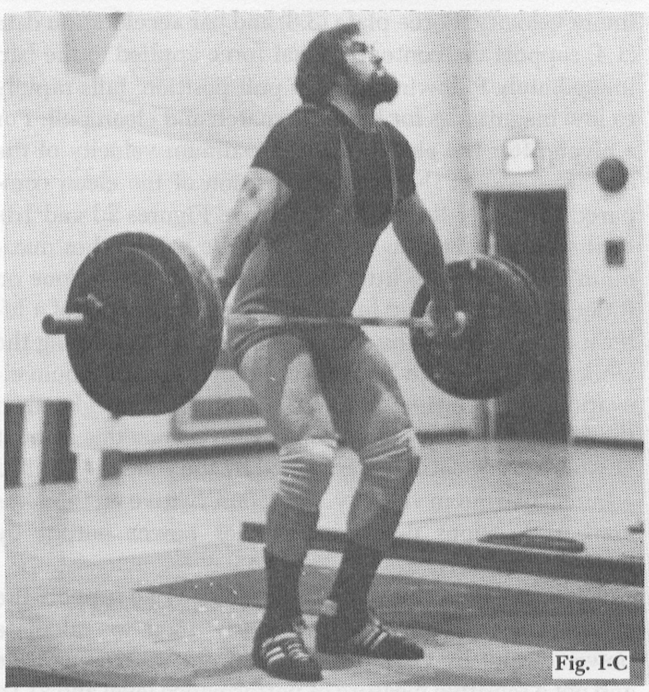


Fig. 1-C

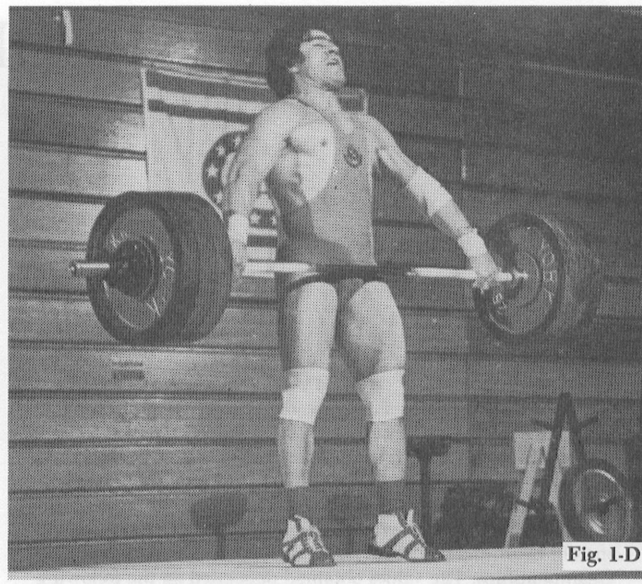


Fig. 1-D

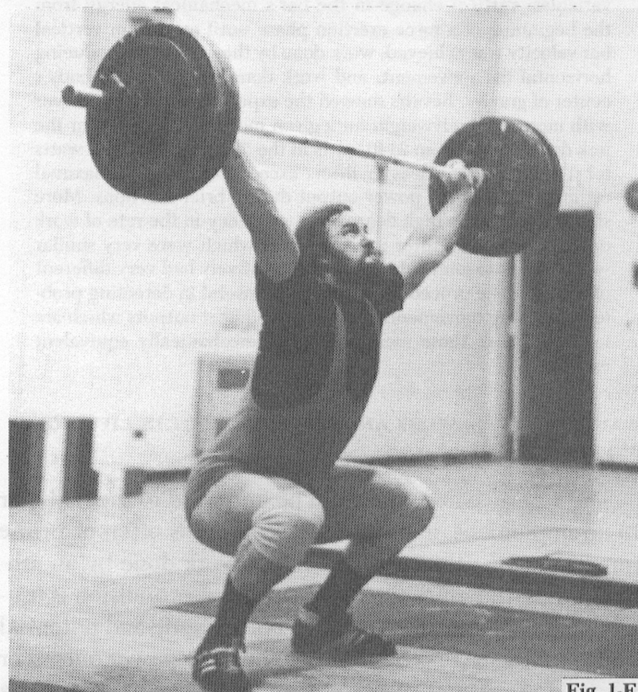


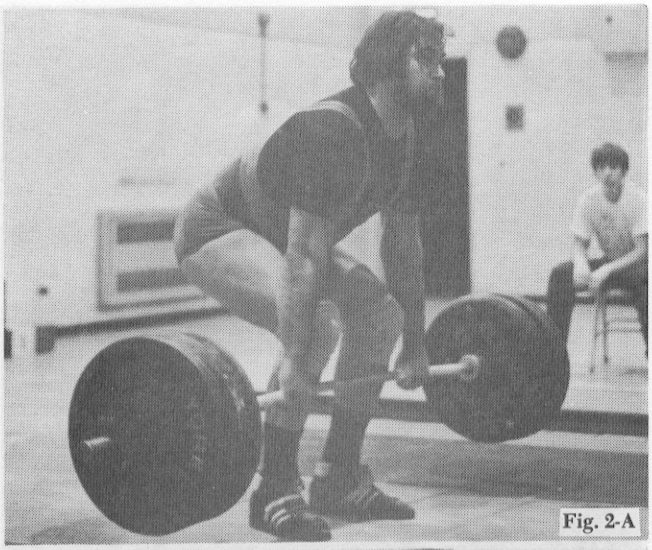
Fig. 1-E

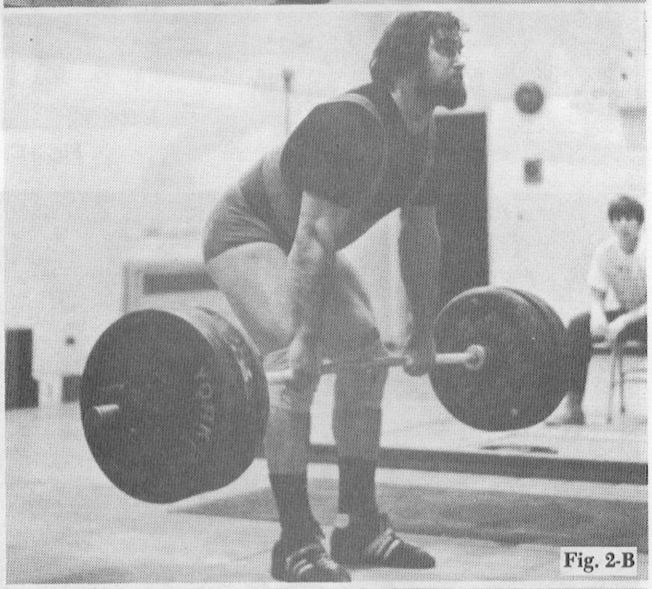
Figure 1—The Olympic snatch lift. (a) starting position ("lift off"); (b) bar at knee height; (c) knees rebent under the bar to begin the "upper" pull; (d) "top pull" position; (e) catching the weight overhead.

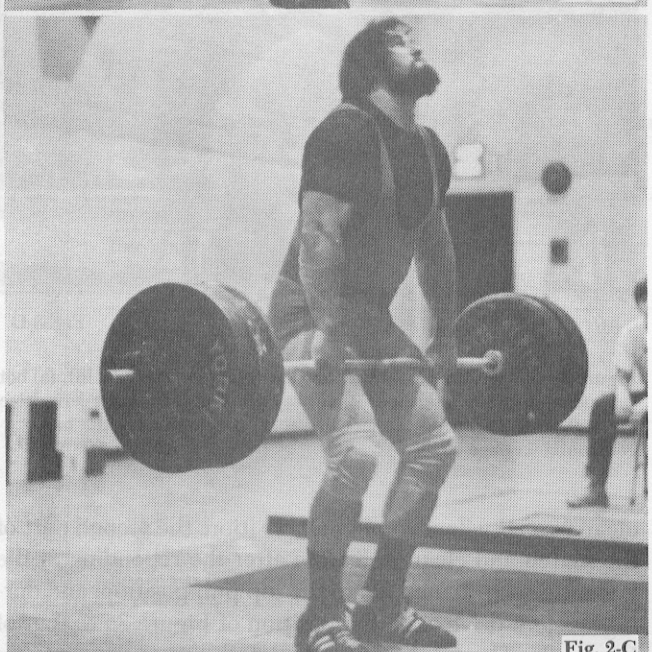
determine the power production of Olympic weightlifters, during different phases of the Olympic lifts, using improved calculation methods.

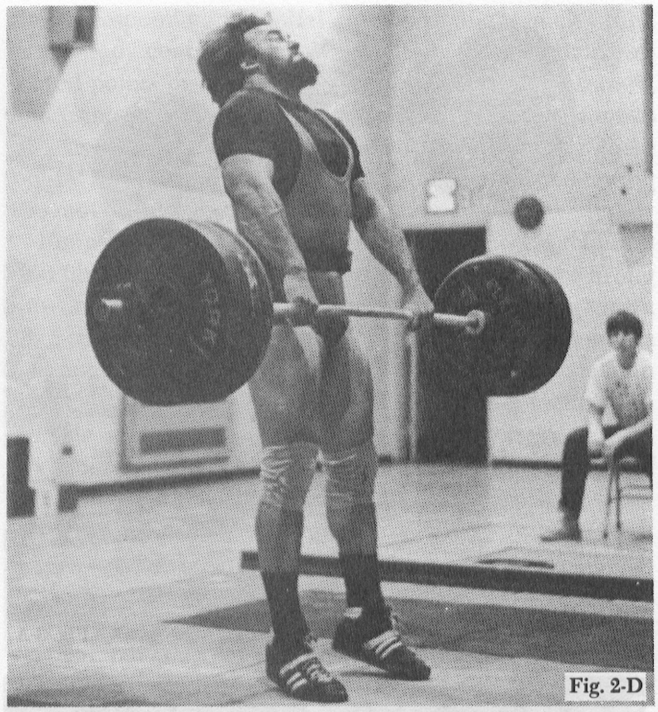
METHODS

The data for this study were obtained from 16 mm films taken at the 1975 U.S. National Weightlifting Championships. Details of the filming procedure and general analysis techniques have been discussed previously (4,5). The po-









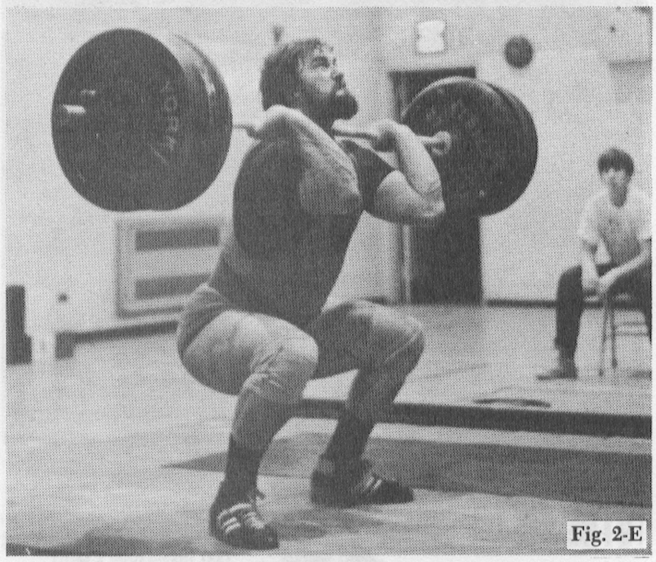


Figure 2—The clean movement of the Olympic clean and jerk lift. (a) starting position ("lift off"); (b) bar at knee height; (c) knees rebent under the bar to begin the "upper" pull; (d) "top pull" position; (e) catching the weight at the shoulders.

sitions of the bar were digitized from the projected film at 0.04 s time intervals for the snatch, clean, and jerk movements. Velocities and accelerations were obtained from the position-time data via a five point moving arc smoothing technique (11). The use of concepts such as kinetic and potential energy, force, acceleration, and work in the analysis of olympic weightlifting has been developed elsewhere (6) and utilized in the calculations.

The work done on the barbell by the lifter from the time the plates left the floor until the top pull position (Figures 1d and 2d) was reached equals the maximum kinetic en-

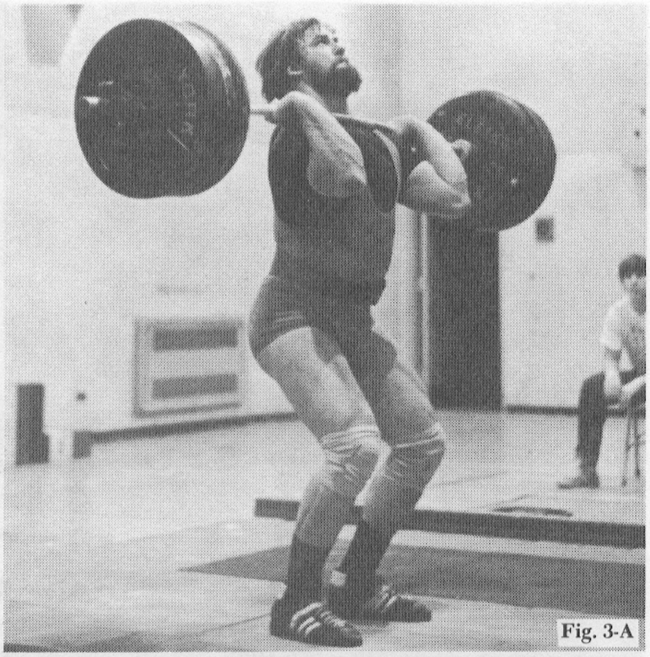


Fig. 3-A

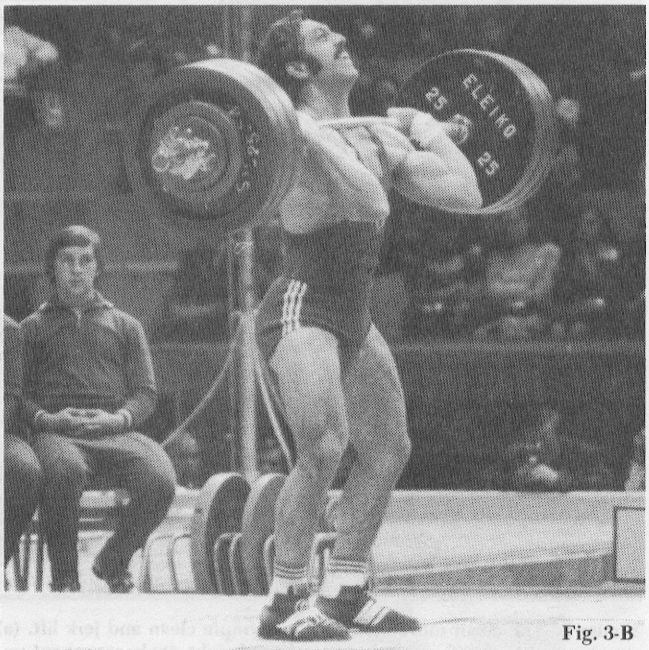


Fig. 3-B

ergy of the barbell plus its gravitation potential energy at that elevation. Dividing this amount of work by the elapsed time yielded the power output of the lifter due to work performed on the barbell for this phase of the lift. Setting the work done on the barbell equal to its potential energy when maximum elevation was achieved, and dividing by the longer elapsed time, resulted in the power developed from work done on the barbell which was used in the previously cited reports on power output by weightlifters. Note that these two methods consider only the work associated with vertical movement of the barbell.

Total work done by a lifter was calculated for five phases of the Olympic lifts. The pull of the snatch and

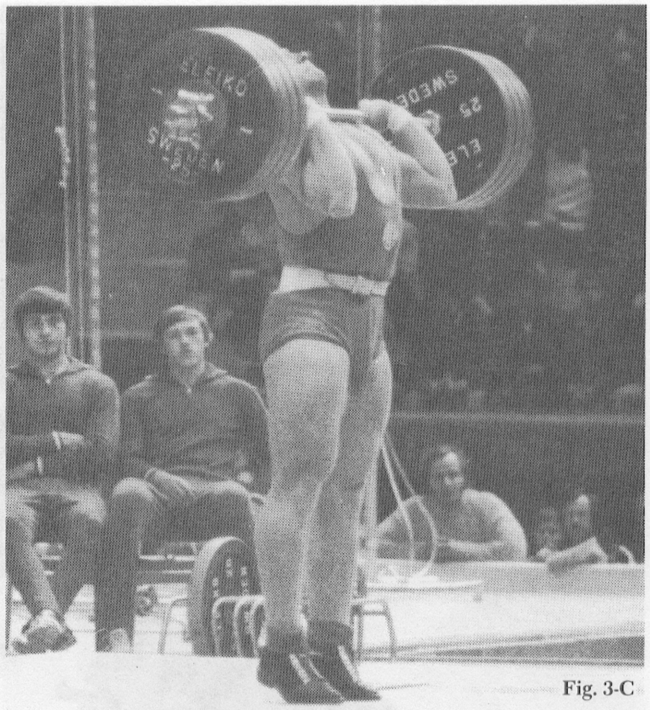


Fig. 3-C

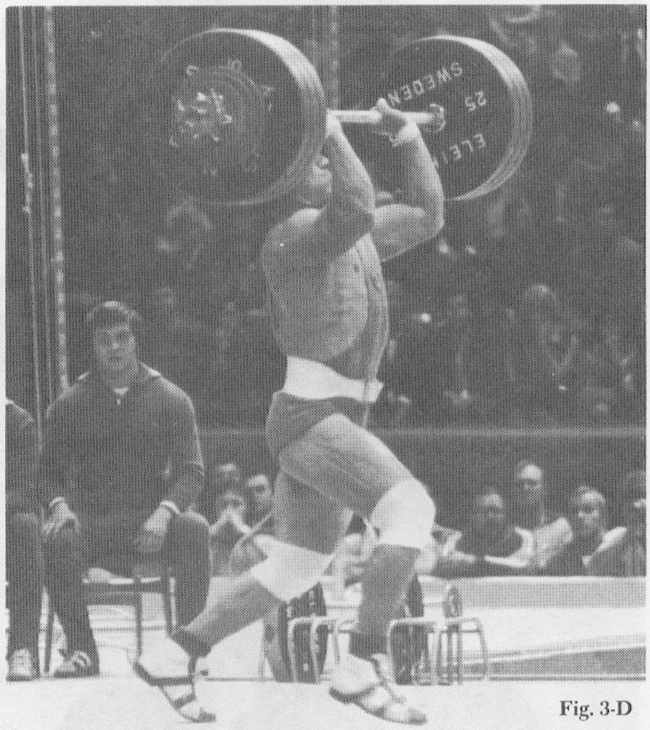


Fig. 3-D

Figure 3—The jerk movement of the Olympic clean and jerk lift. (a) bottom position of the jerk dip; (b) midway position during the jerk drive; (c) final position during the jerk drive; (d) moving under the bar; . . . . **continued on page 58.**

clean from the floor to top pull position, the second part of the snatch and clean pull from after the rebending of the knees (Figures 1c and 2c) to the top pull position, and during the jerk drive from the position of Figure 3a to that of Figure 3c. The total work calculated during these phases

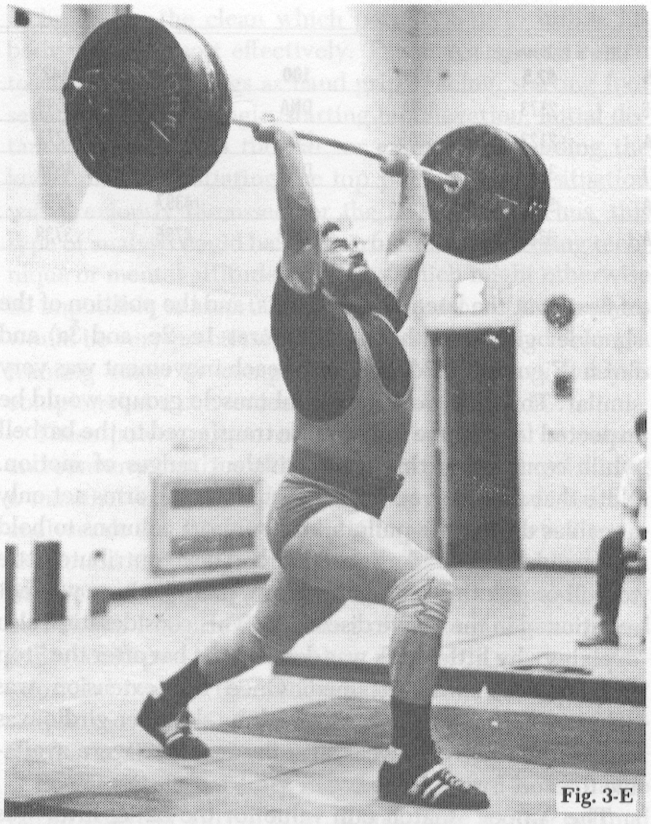


Fig. 3-E

Figure 3—continued, (e) supporting the weight overhead.

included work associated with vertical movement of the barbell, work associated with horizontal movements of the barbell (see reference 6 for the numerical method used to obtain this quantity from horizontal acceleration values of the barbell), and work associated with elevation of the body's center of mass. The work related to vertical movement of the barbell during the pulling movements was calculated from the maximum kinetic energy of the bar and the corresponding potential energy. Changes in elevation of the body center of mass were obtained by digitizing selected points on the body from the required film frames, and using standard values for segment masses and centers of mass. By dividing the total work done during these phases by their durations the total power produced during the movement was obtained.

For a lifter to be included in the analysis it was required that film be available for two of the following three lifting movements: (1) a successful snatch; (2) a successful clean; (3) a successful jerk. In some cases the high speed camera was not up to speed for the clean but did provide valid film for analysis of the subsequent jerk movement. Using these criteria seven lifters were studied, and for two of these seven film was available for two successful movements of the same type.

RESULTS

A comparison of power output values, associated with vertical bar movements only, for the two calculation methods discussed are presented in Table 1. Total power output values for five phases of the Olympic lifts are given in Table 2.

The results presented in Table 1 show that, for both the snatch and clean, the method of using maximum bar elevation in the calculation of power output was a conservative method. The values obtained by this method were 13 to 22% lower than those calculated using the maximum velocity method. The work done by the lifter, however, was found to be 6 to 14% higher when the maximum elevation method was employed. This means that 86 to 94% of the work done by the athlete in lifting the barbell vertically was completed by the time the bar reached maximum velocity. Since the duration of the pulls from "lift off" to maximum velocity ranged from 0.64 s to 0.92 s, while the additional time required to reach maximum elevation was

TABLE 1. Comparison of two methods used to calculate power output related to vertical bar movement.

	Power	Lifter's Bodyweight (kg)								
		52	56	60	82.5	82.5	100	100	110	142
SNATCH	KE(max) + PE	846	956	1064	1545	1444	DNA	DNA	1707	1769
	Time to max KE	0.92	0.80	0.84	0.84	0.84			0.68	0.68
	(joule/sec)	=920	=1195	=1266	=1839	=1719			=2510	=2601
	PE(max)	925	1067	1169	1646	1606	DNA	DNA	1806	1958
	Time to max PE	1.16	1.04	1.08	1.04	1.08			0.92	0.96
	(joule/sec)	=797	=1026	=1082	=1583	=1487			=1963	=2039
CLEAN	KE(max) + PE	869	DNA	973	DNA	1537	1624	1655	1686	1993
	Time to max KE	0.84		0.76		0.88	0.64	0.68	0.72	0.80
	(joule/sec)	=1034		=1280		=1747	=2537	=2434	=2342	=2491
	PE(max)	960	DNA	1108	DNA	1633	1736	1786	1842	2197
	Time to max PE	1.08		1.00		1.08	0.84	0.88	0.92	1.04
	(joule/sec)	=889		=1108		=1512	=2066	=2030	=2002	=2113

DNA: Data not available

TABLE 2. Total power output for five phases of the olympic lifts (watts).

	Lifter's Bodyweight (kg)								
Lifting Movement	52	56	60	82.5	82.5	100	100	110	142
Snatch Pull	1245	1560	1592	2298	2173	DNA	DNA	3400	3599
Clean Pull	1305	DNA	1583	DNA	2123	3205	2988	2949	3273
"Upper" Snatch Pull	1853	2619	2858	3621	3634	DNA	DNA	4807	4554
"Upper" Clean Pull	2206	DNA	2463	DNA	3475	4267	4231	4397	4758
Jerk Drive	2503	2140	2627	DNA	3385	4592	4158	4786	3738

DNA: Data not available

about 0.2 s, these data support the belief that little force is applied to the bar by a lifter after the "top pull" position is attained. Vertical work was a major component of total power output and these values show that, for either method of calculation and either lift, there was an increase in power output with bodyweight. Also evident, for a given calculation method, was the high degree of similarity in snatch and clean power output values for a given lifter.

The total power output values given in Table 2 for five phases of the Olympic lifts show a trend towards higher values with increased bodyweight for any given movement. The values for several of the heavier lifters exceeded Wilkie's (9) estimated maximal human power output capacity in one or more of the movements studied. Snatch and clean pull values were very similar for a given lifter. Likewise, "upper" snatch pull, "upper" clean pull, and jerk drive values were similar for most lifters, and substantially higher than their snatch and clean pull values.

DISCUSSION

Improved performance in Olympic weightlifting can result from increased strength and improved technique. Both of these factors would increase the maximum bar velocity attained during a given lifting movement with a given weight. It is evident that the power output calculation technique developed in this paper would indicate a higher level of performance for the above situation than the conservative method. Increased bar velocity would increase maximum kinetic energy and decrease the movement duration. Both of these changes would increase the power output value, which is a measure of performance level. The conservative method of calculation would result in a higher maximum potential energy for the bar, but would also see an increase in the time from maximum bar velocity to maximum elevation. Thus, the power output value obtained is less sensitive to performance improvement and not as representative of performance level as the maximum kinetic energy method.

The near equivalence of snatch and clean pull values in Table 2 could be explained by considering the similarities of the movements and the large muscle groups which would be expected to be active during these movements (compare Figures 1a-d with Figures 2a-d). The same observations could explain the consistency found among the remaining three values for several of the lifters. The degree of flexion at the knee and hip joints, and the position of the shoulder girdle, at the start (Figures 1c, 2c, and 3a) and finish (Figures 1d, 2d, and 3c) of each movement was very similar. Thus, the same powerful muscle groups would be expected to produce the impulse transferred to the barbell while contracting through equivalent ranges of motion. Note that with correct lifting technique the arms act only as cables during the pulls, and as support columns to hold the weight overhead after the jerk. They contribute little to pull or jerk thrust and, therefore, their position was not mentioned in the above discussion. This consideration also explains why little work was done on the bar after the "top pull" position was attained. Once full extension was achieved at the knee and hip, and the shoulder girdle was raised, the relatively weak arm flexors alone were available to exert force on the bar.

The "upper" snatch pull value for the 52 kg lifter was low relative to his "upper" clean pull and jerk drive values. This may have been an indication that his use of the double knee bend pulling technique was poor. In this technique the knees are rebent and shifted under the bar as soon as it passes knee height (Figure 1b-c). This shift puts the lifter in a strong position to jump with the weight and impart a large impulse to it. Perhaps the lifter in question distributes the impulse to the bar over the entire pull range rather than concentrating it after the rebending of the knees (this idea was discussed in detail in references 4 and 5). This would clearly lower the power output during the upper pull.

The jerk drive value of the 142 kg lifter was very low relative to his "upper" pulling values. This movement appeared almost effortless on film. Perhaps the athlete was exceptionally strong in this phase of the lift, or his technique exceptionally good, so that a maximal effort was not required for success.

The 82.5 kg lifter shows a high degree of consistency in the power output values which are available for two of his snatches and one clean and jerk. It is interesting to note that he was the silver medalist the following year at the Montreal Olympiade. Different analyses of his snatch lifts support the evidence given here for a high degree of performance consistency (4,5).

For a given lifter several movements of each type would have to be analyzed before strong and weak points could be identified with confidence. If, for example, an athlete's clean pull power output is always considerably lower than that of his snatch pull, then he may not be using a pulling technique in the clean which permits him to utilize his body strength most effectively. This may indicate a need to change such things as hand grip spacing, starting foot separation or foot angle, starting hip elevation, initial distance of shins from the bar, or extent of rebending the knees prior to initiating the top pull. A similar situation was previously discussed for the 52 kg lifter. Thus, this type of analysis could be a powerful tool in detecting technique or mental attitude problems which might otherwise be impossible to ascertain. Implementation of this analysis would be very practical. Athletes could be filmed during a training camp or competition, and the power analysis completed at a convenient computer installation.

These power output calculations are global in nature and concerned only with the rate of work produced during a maximal exertion of the total body. If visual and film analyses do not result in a solution to a power deficit problem found in one or more lifting movements studied with the preceeding methods then a more detailed analysis may be helpful. Localized modeling of selected segments and joints could provide information relative to energy generation and transfer differences in higher and lower power output movements. This type of approach has been utilized in walking studies (e.g., see Winter et al. (10)).

Power output capacity may be a limiting factor in the performance of a given lifter. If an athlete is using optimal technique for his body structure (which could be indicated by consistent power output values for biomechanically equivalent lifting movements) then improvement might result from and be measureable as increased power output. It is well known that strength increases alone, as measured by squatting or pressing exercises, do not always result in immediate performance improvement. Power capacity is clearly dependent on factors such as muscle mass, fast/slow fiber area ratios, high energy phosphate availability at the contractile filaments, motor unit recruitment capabilities, and skeletal leverages. Olympic weightlifters are advised to concentrate on speed and explosion in most training movements even if the weight being lifted is too great to permit actual speed in the movement. If future data support these ideas, especially if it comes from analyses of world champion lifters, then the specificity of training concept would be strongly supported.

Power output should be measured in other sports, particularly those involving throwing and jumping, to determine if it correlates with performance. It is reasonable to assume that such a relationship exists and, via the specificity concept, would indicate a need for stressing explosiveness in training.

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