

# WEIGHTLIFTING PERFORMANCE AND TECHNIQUES OF MEN AND WOMEN

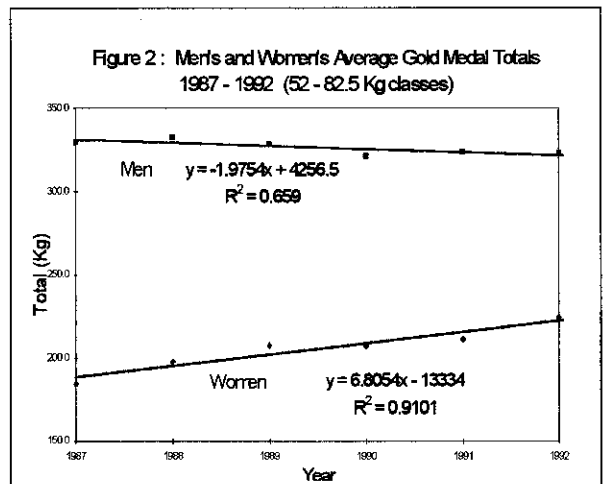
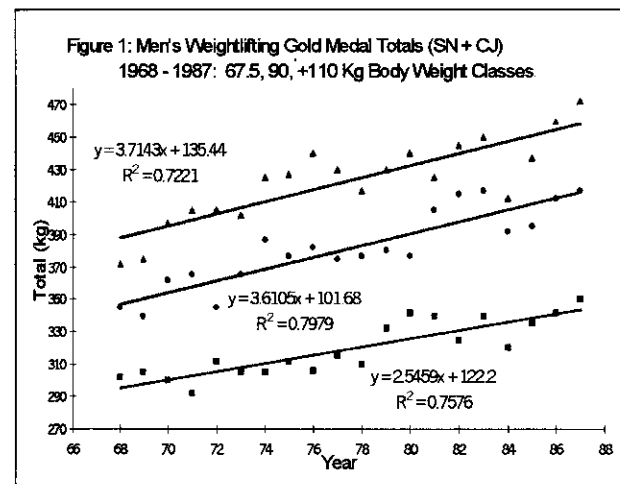
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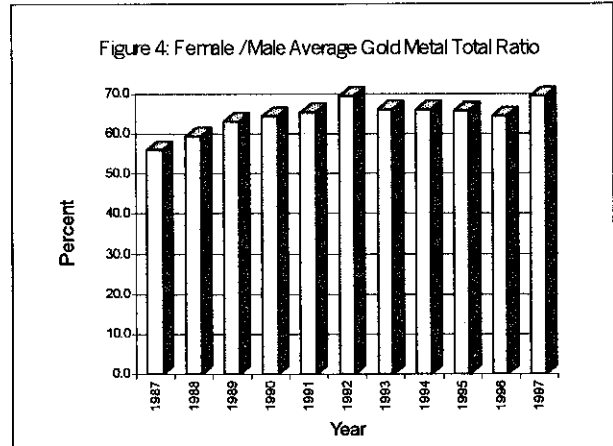
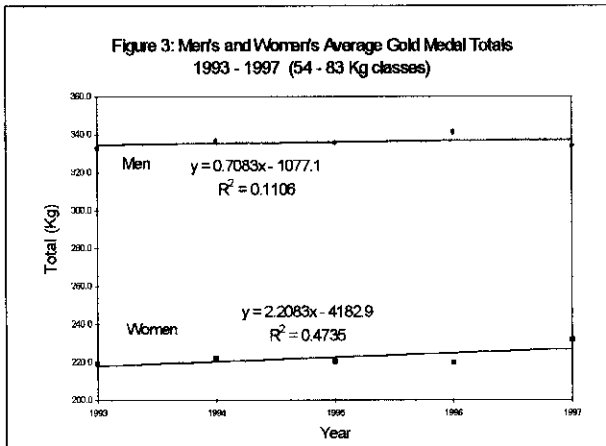
Men have competed internationally in the sport of Weightlifting (WL) through out the twentieth century, with little change in format since 1928 other than the elimination of the clean & press lift in 1972. Participation of females in WL has grown considerably since the first Women's World WL Championships in 1987. Several factors and measurable parameters related to the techniques used by men and women to produce elite performances in WL, and the performance levels themselves, are addressed below. Included are (1) current world records and how they have changed over the last 30 years; (2) how men's and women's records, as well as their mechanical power outputs during competition lifting, compare; (3) how men's and women's performances change with age; (4) kinematic variables used to quantify WL technique; (5) sources of error in the determination of barbell kinematics; (6) the relationship of kinetic and kinematic variables to the double knee bend pulling method; and (7) anthropometric considerations.

## WEIGHTLIFTING PERFORMANCE CHANGES

Figure 1 shows the trends of increased performance in men's gold medal totals for snatch and clean & jerk in the 67.5, 90 and +110 Kg classes at world and Olympic Championships for the 20 year period 1968 to 1987. The average rate of improvement for these three classes was 3.3 Kg per year. Due to the absence of several dominant WL countries at the 1984 Olympic Games in Los Angeles, the true rate of improvement was slightly greater. During the first half of this 20 year period the double knee bend technique, discussed later in this paper, became prevalent for both snatch and clean pulls. From 1987 to 1992, men and women competed in six equivalent body weight classes: 52, 56, 60, 67.5, 75 and 82.5 Kg. Figure 2 shows the trends for average gold medal totals in these six classes for both sexes over that six year period. The linear trends intersect in the year 2003, suggesting that men and women would have equal performances on average for equivalent body weight classes. There is no evidence that technique changes by either group accounts for the average rate of change in performance of almost +7 Kg per year for women and -2 Kg per year for men during these six years. A more likely explanation is the increased influx of female talent into WL during the early years of their participation at the world level, and the increased drug testing requirements for all competitors.



In 1993 body weight divisions were changed for both men and women, with the 54, 59, 64, 70, 76 and 83 Kg classes being common to both sexes. The average gold medal totals and linear trends for these six classes for men and women from 1993 to 1997 are given in Figure 3. Much less convergence in performance occurred, with the men and women increasing at 0.7 and 2.2 Kg per year, respectively. Figure 4 summarizes the comparison of average women's winning performances to those of men in equivalent body weight classes for the eleven years that women have competed in world WL championships. Excluding the first two "developmental" years, the 0.66 average ratio is in good agreement with other published results, as discussed in an abstract presented at this conference [1].



Calculation of mechanical power output for athletes competing in selected world WL championships showed that women's values averaged 63% that of men for snatch and clean pulls (21.8 vs. 34.3 W/Kg), but 74% for second pulls (39.2 vs. 52.6 W/Kg) [2,3]. Women's power values for faster movements versus slower movements, such as snatch compared to clean or second pull compared to complete pull, were consistently a higher percentage of men's values.

Analysis of age group world records indicated that men's WL performance decreases at a rate of about 5.4% for each five year age group beginning with the 40 to 44 year old group. Women's age group data is limited, probably due to many fewer years of widespread participation, but currently indicates a greater rate of decrease with age than that for men [1].

## BARBELL KINEMATICS

The most common objective approach to technique analysis for WL is the determination of barbell kinematics during competition, particularly barbell trajectory and velocity. The vast majority of published data indicates a trajectory pattern that relates well to the "double knee bend" technique used for both the snatch and clean pull. This technique is ideally characterized by a start or "lift-off" position with the knee and hip joints flexed, the torso straight, and the shoulders over or in front of the bar. During the first pull the knees and hips extend while the back remains straight, at a nearly constant angle with the horizontal, and with the shoulders in the same position as at the start relative to the bar. As the bar passes knee height, a reorientation of the body occurs with the knees flexing (second knee bend) and moving forward under the bar as the hips move forward with the bar near to or in contact with the thighs. As the still straight torso reaches a nearly vertical position the second pull begins and the bar accelerates rapidly to reach maximum vertical velocity as the body fully extends upward, and in some cases slightly backward as well.

In general, during the first pull the barbell moves upward and backward toward the athlete, but during the transition and early part of the second pull it moves upward and forward. Toward the end of the second pull the bar ideally moves straight upward, and finally curves back toward the athlete as it begins to descend while the athlete shifts his or her body into the squat position under the bar to receive it overhead for the snatch or at the shoulders for the clean. Due to the barbell weight typically being one to three times body weight, these backward and forward movements of the bar during the pull are closely related to the athlete's balance on his or her feet. Force plate studies [4] in both the training and competition setting have shown that during the first pull, the athlete's balance point moves backward toward the heels of the feet as the bar moves toward the athlete; during the transition and initial second pull, the athlete's balance point moves forward toward the toes while the bar moves forward and away from the athlete (Figure 5). Balance shifts generally precede horizontal bar movements.

Figure 5: Horizontal bar movement (left), backward - forward balance shifts on the feet (right). Vertical axis = bar height.

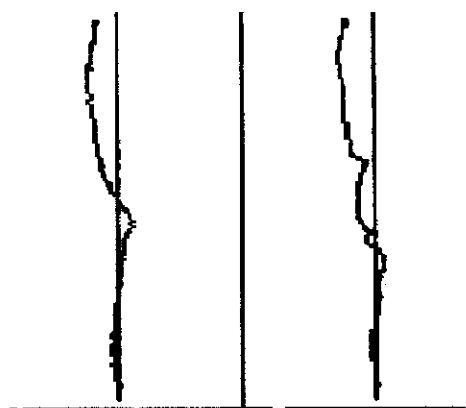
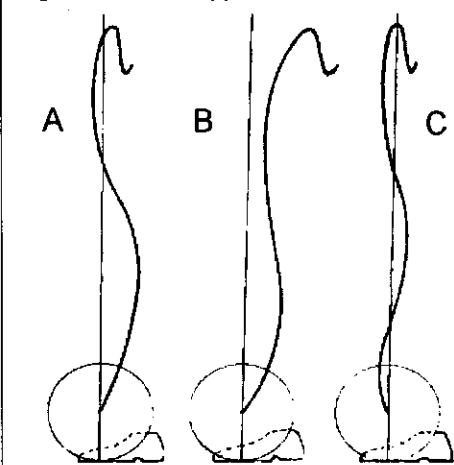


Figure 6: Basic types of bar trajectories.



A few issues related to the general description of the pulling technique and associated barbell kinematics presented above require some detailed discussion. The double knee bend pulling technique has been used almost exclusively by elite weightlifters for about thirty years. The backward and forward balance shifts on the feet, corresponding to backward and forward bar movement relative to the athlete's body, are required by mechanical principles of balance and stability. Vorobyev [5] has proposed three basic types of bar trajectories, as illustrated in Figure 6. The pattern of barbell trajectory that exemplifies an appropriate and mechanically efficient pulling technique is type A. I have reviewed my 16mm film analysis results for 37 snatches and 30 cleans performed by male world champions and world record holders in competitions from 1978 to 1984. About 55% of these lifts were performed with a type A trajectory, and most of the remaining 45% with type B (Figure 6). Results of my film analyses of 16 snatch and clean lifts by the nine gold medalists at the 1987 Women's World WL Championship showed a bar trajectory distribution of 62% type A, 31% type B, and 6% type C. Baumann and coworkers [6] have reported trajectory results for 82 snatches from

the 1985 World WL Championships. They pointed out the prevalence of type B curves but gave no indication of finding any of type C. Recently published results by Hiskia [7] of 669 men's and 330 women's snatch lifts from world and European championships in 1993 and 1994 show type A, B and C trajectories to be distributed 8.5%, 42.9% and 48.5% for men, and 22.4%, 25.5% and 52.1% for women. Has pulling technique really changed so much over the last decade? In particular, is the

type C pulling pattern, which is inefficient and detrimental to balance, as prevalent as the data of Hiskia indicates? No definitive answer can yet be given, but the following two factors should be considered before interpreting these recent results.

Although Hiskia's data [7] was collected at the highest level competitions, not all competitors can be expected to exhibit efficient and consistent lifting technique. Baumann et al. [6] reported greater variation in horizontal bar movement for the athletes snatching the least weight compared to those who lifted the most at the 1985 world championships. The data I referred to above from 1978 to 1984, as well as the women's data from 1987, were for world champions and world record holders exclusively. When a very large sample of athletes is analyzed at any competition a variety of techniques will be found, many of which are not exemplary of what is desirable based on mechanical principles, nor generally accepted coaching guidelines. A more important factor, however, is the method used to determine bar trajectory. Most methods that have been used to determine bar kinematics have been based on the horizontal and vertical position coordinates of a single point, usually one end of the bar. This method does not account for rotation of the bar about a vertical axis through its center. Such a rotation is common, and usually due to asymmetrical development of an athlete's musculoskeletal structure, or inappropriate foot position and distance of the ankles from the bar at lift-off [5].

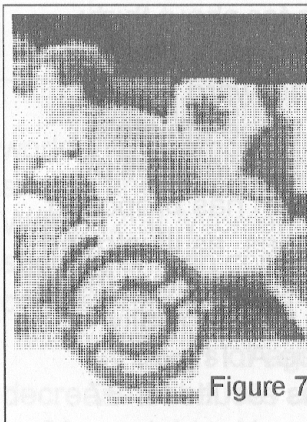


Figure 7

The use of film and video to record lifting performances for analysis has the disadvantage of requiring manual or computer automated digitization, which can delay the reporting of kinematic results from minutes to hours. A great advantage for accuracy, however, is that a visual record of each lift is available and permits the elimination of lifts from analysis that exhibit vertical axis rotation. This is very important, since a barbell that rotates counter clockwise, as seen from above, has its left side move backward toward the athlete's body while its right side moves forward away from the athlete, as illustrated in Figures 7 and 8. (Note: digitizing the two white spots added to opposite ends of a disc diameter, as seen in Figures 7 & 8, and defining the mid point as bar position, is more accurate than digitizing the visible end of the bar.) Depending on which side of the bar is followed for analysis the resulting trajectory can be completely different, as pointed out by Vorobyev [5], and extensively documented in recent years at the US Olympic Training Complex in Colorado Springs [8]. The trajectory distributions I reported above were based on analyses of 16mm film, and lifts showing extensive rotation were not included.

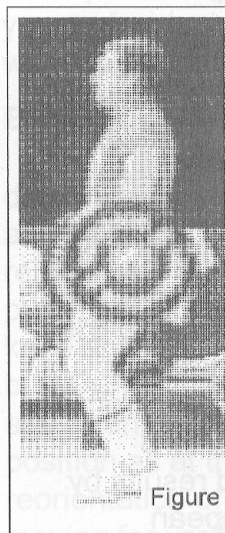


Figure 8

In 1982 and 1983 I conducted numerous WL analysis projects, involving our best candidates for the 1984 US Olympic team, at the Colorado Springs Training Complex. Most kinematic analyses were performed using 16mm film, but some were performed using a Selspot system that automatically followed a small infrared diode attached to one end of the barbell. Another piece of equipment used was a Sony prototype video based system that had the ability to automatically digitize a bright spot in the field of view, such as small light bulb attached to one end of the bar.

In both cases results were available quickly, but with the disadvantage that neither system could be used at competitions due to the hard wire connection needed to the bar and, in the case of the Selspot system, no visual record was available to determine which lifts included vertical axis rotation. The extensive data reported by Hiskia [7] was obtained with a new type of equipment called the V-Scope, which utilizes both infrared and ultrasonic technology to track one end of the barbell without the need for a hard wire connection. This system provides immediate data, but lacks a visual record to permit identification of any analyzed lifts that involve extensive vertical axis rotation. Thus, at least some of the large number of results reported using the V-Scope may include erroneous horizontal motion data and result in improper classification of bar trajectory type. Fortunately, parameters related to vertical bar motion are not affected by this bar rotation problem. Three dimensional analysis methodology is technically more involved, but if applied and interpreted properly, can provide accurate bar kinematics whether or not bar rotation occurs.

The second most common kinematic parameter associated with WL technique analysis is velocity. Horizontal velocities are small and can be affected by the problems of measurement discussed above. Vertical velocities are greater and less problematic to determine. The vast majority of hundreds of snatch and clean lifts, by athletes of both national and international caliber, that I have analyzed using primarily film and video records from 1974 through 1987, have exhibited an initial vertical velocity peak during the first pull of the double knee bend technique and a higher second vertical velocity peak during the second pull. This was also the finding of Baumann et al. [6], Hiskia [7], and other investigators reporting on smaller numbers of subjects. A steady rise to a single peak in vertical velocity is uncommon, but if found is usually produced by smaller sized athletes [7]. Some studies of vertical bar velocity profiles during the classical lifts may erroneously conclude that no velocity peak occurs during the first pull. This may be due to a low sampling rate ( $\leq 25$  Hz) and / or the calculational method used to determine velocity from position - time data. I have found that when using 50 versus 25 Hz sampling rates, and a moving arc calculation method, the velocity peaks are greater and more distinct at 50 Hz. Published results have also indicated that the selection of parameters, such as cut-off frequency and error estimate, when using a spline function or digital filter for data smoothing, can affect the magnitude or even the existence of a velocity peak during the first pull [9].

## **KINETIC PARAMETERS**

The primary kinetic variables discussed in connection with WL technique are the vertical force exerted on the bar and the vertical ground reaction force (VGRF) exerted on the lifting platform. The former parameter is usually determined from vertical bar acceleration. This method is prone to calculational errors even more extensive than those discussed above for the calculation of vertical bar velocity. Use of an accelerometer would be more accurate but not a viable choice for use during competitions. A force plate is very accurate for determining VGRF and has been used successfully in laboratory and training hall settings, as well as in major international competitions [4, 6]. This latter parameter has the advantage of including forces required to elevate both the athlete's body and the barbell during execution of the classical lifts. Studies determining one or both of these kinetic parameters have, with few exceptions, found a double peak in force corresponding to the first and second pull of the double knee bend technique, and a double peak in vertical bar velocity.

Balance on the feet, as discussed earlier in connection with bar trajectory, can also be determined using a force plate. Thus, the force plate is a valuable tool to help validate backward and forward bar motion during the pull via backward and forward balance shifts by the lifter, as well as dual peaks in vertical bar velocity via direct vertical force measurement and application of dynamic equations of motion. Mechanical power output, mentioned in the performance section of this paper, is another useful kinetic parameter which has been discussed in detail elsewhere [3].

## **ANTHROPOMETRY**

A final topic for consideration, which has received far too little attention in the literature, is anthropometric characteristics of weightlifters. Horizontal bar trajectory patterns, maximum bar height for successful lifts, and bar velocity profiles during the pull, are a few important characteristics of lifting technique that depend on the anthropometric characteristics of athletes. Body height versus weight category is another important issue. Vorobyev [5] presented ranges of acceptable height for elite performance in each body weight division 20 years ago. What are the corresponding ranges today for the new weight categories? Do elite women weightlifters follow the same height versus weight class trends as men? How do longer or shorter than average upper or lower extremity lengths or torso lengths affect the characteristics of pulling technique? These are questions which have received too little attention and to which I have no answers, but which need to be investigated in detail. Thus, I encourage researchers in weightlifting to examine these questions along with those that have traditionally received more frequent attention.

## **REFERENCES**

- [1] Rozenek, R. and J. Garhammer. Male - female strength comparisons and rate of strength decline with age in weightlifting and powerlifting. Conference book, International Conference on Weightlifting and Strength Training, Lahti, Finland, 1998.
- [2] Garhammer, J. A comparison of maximal power outputs between elite male and female weightlifters in competition. *Int J Sports Biomechanics* 7(1):3-11, 1991.
- [3] Garhammer, J. A review of power output studies of Olympic and Powerlifting: ... *J Strength Cond Res* 7(2):76-89, 1993.
- [4] Garhammer, J. Weight Lifting and Training. In: Biomechanics of Sport (C.L. Vaughan, ed.), CRC Publishers, Inc. Boca Raton, FL, Chapter 5, pp. 169-211, 1989.
- [5] Vorobyev, A.N. A Textbook on Weightlifting (translated from Russian by W.J. Brice). International Weightlifting Federation, Budapest, 1978.
- [6] Baumann, W. et al. The snatch technique of world class weightlifters at the 1985 world championships. *Int J Sports Biomechanics* 4(1):68-89, 1988.
- [7] Hiskia, G. Biomechanical analysis of world and Olympic champion weightlifters performance. Proceedings of the IWF Weightlifting Symposium, Ancient Olympia, Greece. International Weightlifting Federation, Budapest, pp.137-158, 1997.
- [8] Jones, L. Coaching Platform. *Weightlifting USA* 12(5):8-10, 1994.
- [9] Garhammer, J. and W.C. Whiting. Comparison of three data smoothing techniques for determining weightlifting kinematics. *Scand J Sports Sci* 11(3):97-104, 1989.