

Analysis of Bar Paths During the Snatch in Elite Male Weightlifters

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SEVERAL STUDIES HAVE INVESTIGATED the kinetics and kinematics of snatch technique (2-4, 7, 8, 14-16). There are also various articles and opinions in coaching journals and scientific journals on the technical aspects of the snatch and related lifts (1, 2, 4-6, 15-17, 19).

The bar path suggested as "correct" in many coaching articles published in the U.S. is similar to that seen in European, Asian, and Canadian lifters in some regions of the bar trajectory, while being quite different in other regions. Examples of bar paths are shown in Figures 1 and 2.

The literature suggests several ideas about horizontal displacement (position of the catch relative to the starting position of the bar) during the lift. Some coaches and sport scientists suggest that no horizontal displacement is best (16). Others say a backward displacement is preferred (5, 8, 12, 15).

Almost all the research and coaching articles indicate that large horizontal displacements are not good. However, most of the non-U.S. lifts discussed in the literature (15) as well as lifts in European competitions (Hiskia, 14, personal communiqué) have a rather large backward displacement of the bar (approx. 10 to 20 cm) relative to the starting position.

It follows that this large rearward movement of the bar would require a backward movement of the body (and feet) in order to keep the base of support under the bar, a movement most U.S. coaches would consider undesirable.

Regardless of coaching philosophy, the confounding issue in all of the kinematic investigations from competitions is that it appears no single variable can reliably predict success during the lift. It seems logical that the more horizontal the bar's move-

ment, the greater the energy expenditure and strength required to stabilize the bar in the catch position.

However, it appears that large horizontal movements, either forward or backward, do not by themselves determine the outcome of an attempt in the snatch. Bar tracings showing widely varying bar paths have been recorded for both successful and unsuccessful lifts. Comparing bar height attained during the lift is not practical without an in-depth anthropometric analysis of each lifter.

Bar velocities and drop velocities (lifter moving under the bar) also show great inter- and intralifter variation. Many factors can influence the outcome of a snatch attempt. Therefore, whatever determines success is likely to be multifactorial in nature.

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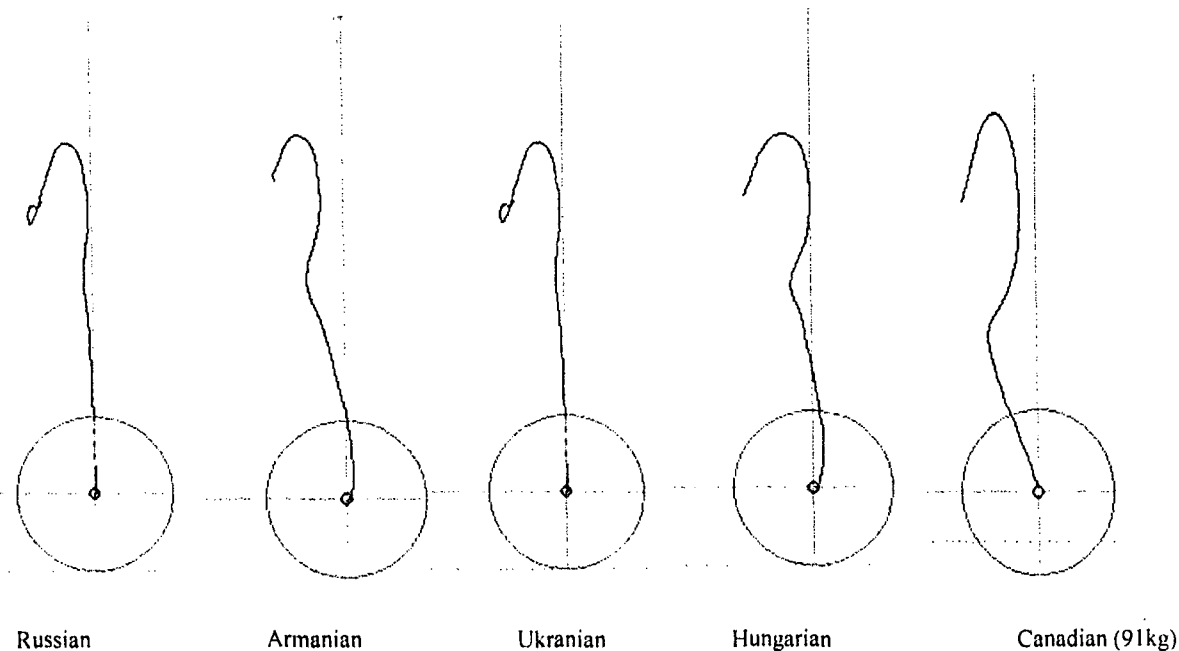


Figure 1 Bar tracings of successful attempts from various countries (from V-scope data files, 99K class).

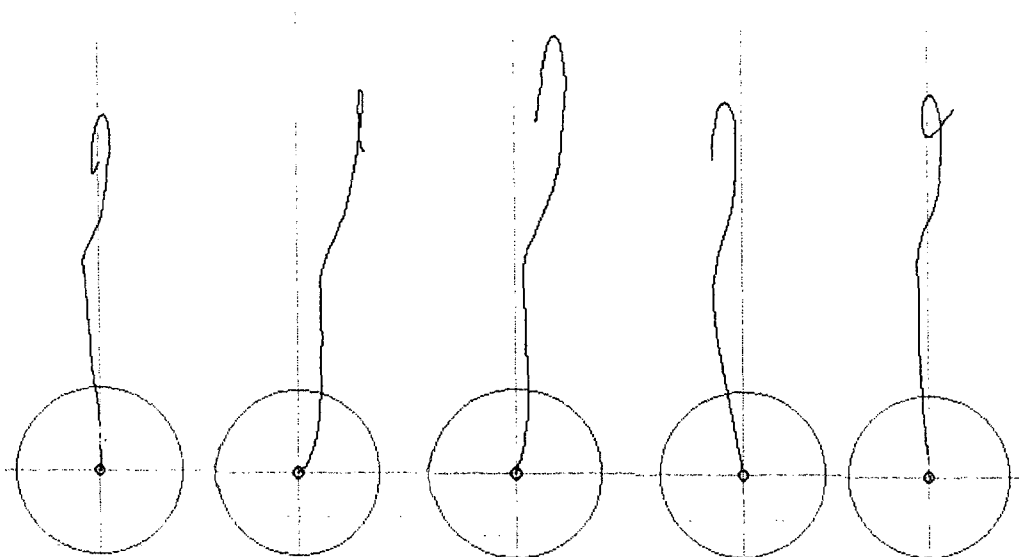


Figure 2 Bar tracings of successful lifts from U.S. lifters in the 1996 National Championships.

■ Our Analysis

Using the V-scope, we set out to analyze the snatch bar path to identify markers of successful technique during an international competition. We also compared U.S. and non-U.S. lifting techniques (bar

path) to see what constitutes successful technique. The subjects were male competitors in the snatch at the 1996 U.S. National Weightlifting Championships and the concurrent North American, Central American, and Caribbean Island Championships (NACACI).

Following an initial analysis of the lifts, attempts from 43 competitors (30 U.S. lifters) from the 54- to 91-kg classes were used in the final analysis (86 total attempts, successful and unsuccessful). Bar paths of the snatch were analyzed using the V-scope 120

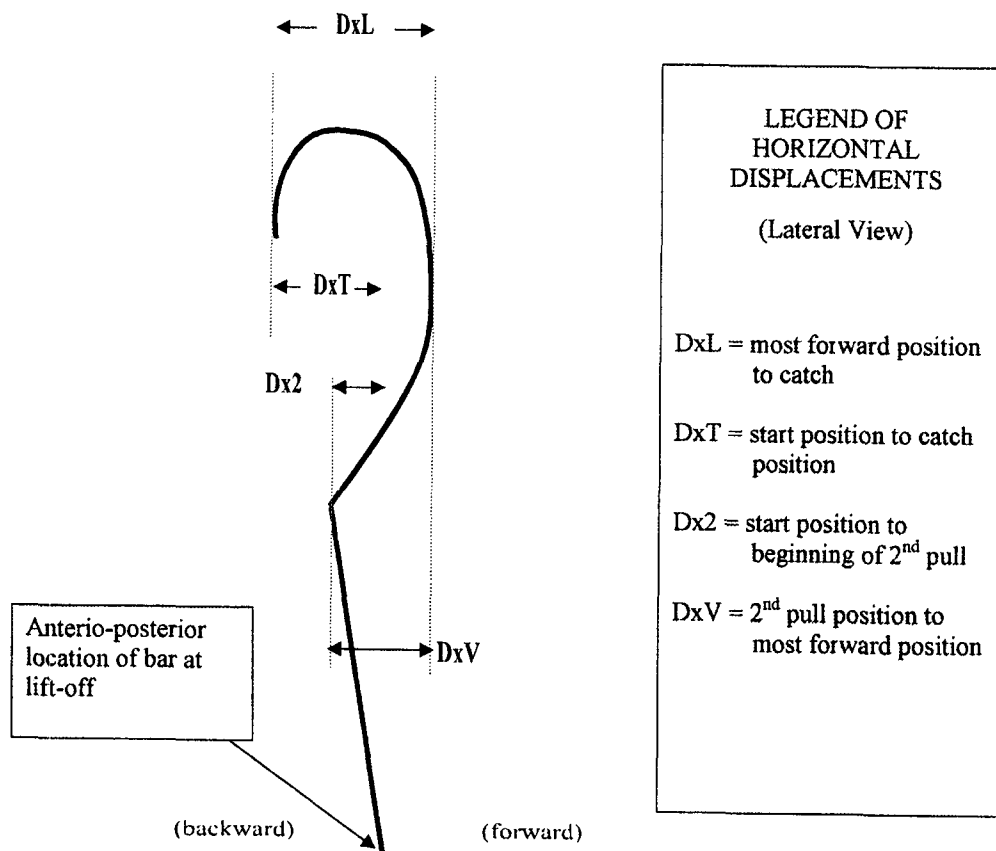


Figure 3 Bar displacement parameters (trajectory exaggerated for clarity).

weightlifting analyzer (Lipman Electronic Engineering Ltd., Ramat Hahayal, Israel).

The V-scope is a movement analysis device using infra-red and ultrasound to track the end of the bar during weightlifting. Reliability and accuracy of the V-scope have been carefully checked in our laboratory and are quite acceptable.

Selection of the 86 lifts used for analysis was based on being able to capture the entire lift on the V-scope. The parameters recorded and analyzed from the V-scope software were as follows:

- pV1 = peak vertical velocity during 1st pull;
- pV2 = peak vertical velocity during 2nd pull;

- pFy = peak vertical force;
- T = time to peak force;
- pPow = peak (instantaneous) vertical power;
- DxT = net horizontal displacement: starting position to the point of overhead catch;
- Dx2 = horizontal displacement from start to beginning of 2nd pull;
- DxV = horizontal displacement from start of 2nd pull to most forward position during 2nd pull;
- DxL = horizontal displacement from most forward position during 2nd pull to catch position (i.e., the "Loop");
- D3D = multiplaner (x, y, and z) from start of 2nd pull to catch position (entire distance

the bar travels from start of 2nd pull until catch position).

All these parameters are relative to the bar only and do not incorporate work performed by the body (see diagram in Figure 3). The V-scope only tracks one end of the bar in a manner similar to cinematography/videography, thus interpretation can be limited. However, the V-scope has a distinct advantage over cinematography/videography in that immediate feedback can be given to the lifter and the coach.

For this study, the subjects were grouped according to their respective weight classes; in addition, the data were grouped into bar mass relative to body mass (KG/KG). This grouping was used

to ascertain the general effects of body size/strength on the variables investigated.

It is possible that athletes lifting more weight per kg of body mass would display different bar paths than relatively weaker lifters. The relative groups were: 1.5–1.59; 1.6–1.69; 1.7–1.79; and 1.8+.

Statistical analyses of the V-scope-generated variables included multiple analyses of variance (MANOVA) for analysis of successful and unsuccessful attempts within and between body weight classes and groupings for KG/KG. Pearson product moment correlations were used to identify relations among variables and regression analysis; univariate statistics were used to investigate variables as to their contribution to lifting success. The alpha level was $p \leq 0.05$.

■ What We Found

Velocities and power outputs from our study were similar to those of other studies that employed cinematographical techniques (11, 16), which supports the validity of the instrument used for data collection (Tables 1 and 2).

The statistical analyses revealed that the relatively weaker lifters (KG/KG) tended to have lower values for pFy and pPow and also looped the bar to a somewhat greater degree. Correlations showed several strong values resulting from successful lifts ($n = 42$) (Tables 3 and 4). However, the statistical methods we employed did not show any variables that clearly separate a successful from an unsuccessful lift.

This data clearly shows the difficulty in predicting the success of weightlifting movements. Furthermore, the data strongly indicates that making or missing a lift is a multifactorial process.

Table 1
Means (\pm SD) for Total Group, Successful vs. Unsuccessful Attempts

Success	pV1 (m/s)	pV2 (m/s)	pFy (N)	pPow (watts)	DxT (m)	DxL (m)	Dx2 (m)	DxV (m)	D3D (m)
Yes (42)	1.40	1.85	2032	3316	-0.074	-0.096	-0.053	0.079	1.28
SD	0.17	0.11	422	696	0.12	0.07	0.05	0.04	0.08
No (44)	1.36	1.81	1925	3142	-0.089	-0.108	-0.052	0.074	1.31
SD	0.17	0.19	376	682	0.11	0.06	0.04	0.04	0.09

Table 2
Means (\pm SD) for Successful Attempts, Relative Body Mass Groups

Group	pV1 (m/s)	pV2 (m/s)	pFy (N)	pPow (watts)	DxT (m)	DxL (m)	Dx2 (m)	DxV (m)	D3D (m)
1 ($n = 10$)	1.39	1.79	1706 [†]	2728 [†]	-0.14 [†]	-0.13	-0.07	0.06	1.31
SD	0.6	0.3	166	219	0.03	0.03	0.01	0.01	0.11
2 ($n = 12$)	1.45	1.89	1963 [‡]	3335	-0.02	-0.07	-0.05	0.09	1.27
SD	0.05	0.02	60	93	0.04	0.02	0.02	0.01	0.02
2 ($n = 8$)	1.40	1.82	2144	3385	-0.02	-0.07	-0.05	0.09	1.27
SD	0.05	0.05	133	248	0.04	0.02	0.02	0.01	0.03
4 ($n = 12$)	1.39	1.87	2298	3750	-0.07	-0.09	-0.04	0.07	1.29
SD	0.04	0.03	97	194	0.07	0.01	0.01	0.07	0.02

Note: [†]Different from 2–4; [‡]Diff. from 3–4.

However, several possible explanations can be addressed.

Although the statistical results indicate there were no significant differences between missed and made attempts for pFy and pPow, it is possible that seemingly minor changes in force or power application can influence the outcome of a lift. Garhammer (10, 11) has demonstrated that successful snatch attempts depend on the magnitude and rate of force production and power application to the bar.

Our present data is in agreement with Garhammer (10), as the pFy's and pPow's were somewhat higher during successful attempts. As the weight that was lifted relative to body mass in-

creased, the force and power outputs also increased (Table 2).

Interestingly, we observed that the heavier the weight lifted relative to body mass, the less the horizontal displacement of the bar (catch relative to starting position). This suggests that maximum strength plays an integral role in making the lift agree with previous research (16).

Another important factor is the direction of the applied force. The instrumentation did not allow for calculation of the exact angles in which the bar was traveling, but vertical and horizontal displacements for portions of the bar path were calculated.

One area of concern for coaches and athletes has been the

degree of looping in the bar path. The loop is defined as the horizontal displacement from the bar's most forward position during the 2nd pull to the catch position (Figure 3). It was hypothesized that the magnitude of the loop or the amount of displacement forward or backward from the liftoff position would greatly influence the success of a lift.

The trends in the data do suggest that a general backward displacement of the bar is likely related to success. Of 42 successful attempts, 32 (76%) exhibited a backward displacement of the bar (bar caught behind the starting point). Also, in 11 of 17 (68%) attempts in which DxV (horizontal displacement from start of 2nd pull to point where bar begins to move vertically) was greater than 10 cm, the lifter caught the bar forward of the bar's starting position; and 7 (64%) were failures.

When an athlete's unsuccessful attempt is compared to his successful attempt at the same weight ($n = 11$), data typically indicate less looping ($n = 7$), a higher peak vertical force ($n = 9$), and a slightly rearward 2nd-pull starting position for successful attempts.

Six of these successful attempts involved a combination of a more rearward 2nd-pull starting position (>2 cm more rearward), higher peak vertical force (2110 vs. 1973 N), less looping (3.0 cm less), and a top position not quite as far behind as in the missed attempt (12.5 vs. 16.6 cm).

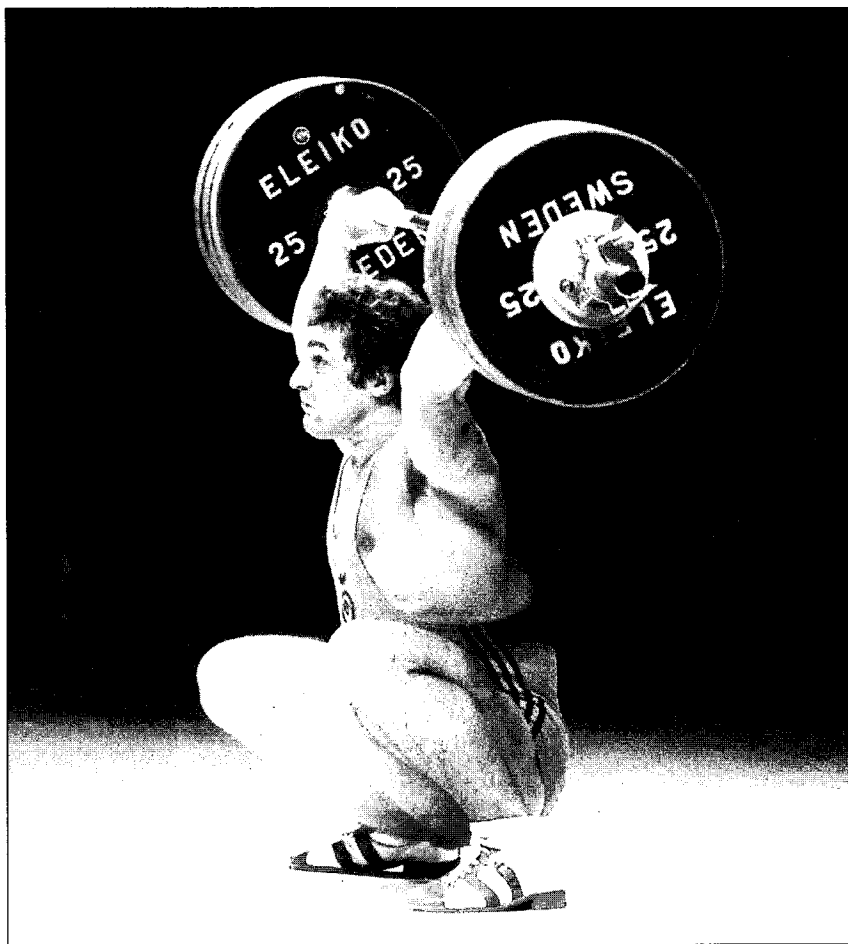
Pulling the bar with a net rearward displacement and jumping back is a technique commonly observed among Asian, European, and Canadian lifters (Figure 1). The rationale for moving the bar backward is that by markedly shifting the weight (combination

of lifter and bar mass) rearward and continuing to direct the force on the bar up and rearward for as long as possible, more of the forces applied in the 2nd pull will be directed vertically.

The lifter can accomplish this rearward pull by (a) markedly shifting the foot center of pressure toward the heel at liftoff and maintaining a flat foot stance as long as possible, and (b) initiating and finishing the 2nd pull while keeping the hips over or behind the ankles. This will result in the body leaning backward as the hips and knees fully extend and the shoulder shrug (trapezius) and plantar flexion (gastrocnemius) complete the pull.

This technique is advantageous for several reasons (15): First, moving the trunk upward during final hip extension enhances one's ability to use body mass to project the bar upward. Second, this position will allow for a greater vertical velocity and vertical height to be achieved, increasing the chance of success because of the ability to project more force vertically during the 2nd pull.

If the lifter allows the weight to shift forward toward the toes at liftoff, the bar will be moving away from the base of support upon entering the transition phase between the 1st and 2nd pull. However, if the lifter brings the bar



Victor Sots (of former USSR) showing a good overhead position in the snatch.

Table 3
Significant Correlations for Successful Attempts,
Lifters Missing, Then Making the Same Weight (n = 11)

Relationship	Pearson r	r ²
Catch position to amount of loop (DxT vs. DxL)	0.90	0.81
Catch position to 2nd pull position (DxT vs. Dx2)	0.75	0.56
Catch position to amount of hiping (DxT vs. DxV)	0.84	0.71
Amount of hiping to amount of loop (DxV vs. DxL)	0.66	0.44
Peak vertical force to peak power (pFy vs. pPow)	0.92	0.85
Peak power to peak 1st pull velocity (pPow vs. pV1)	0.62	0.44

Table 4
Correlations for 42 Successful Attempts

Relationship	Pearson r	r ²
Catch position to amount of loop (DxT vs. DxL)	0.85	0.67
Catch position to 2nd pull position (DxT vs. Dx2)	0.84	0.71
Catch position to amount of hiping (DxT vs. DxV)	0.51	0.26
Peak vertical force to peak power (pFy vs. pPow)	0.89	0.79

toward the lower leg during the 1st pull and moves the body backward, the center of pressure will move toward the heels during the transition. This is the technique espoused by the majority of coaches regardless of nationality. Yet this technique is not always observed.

During the 1st pull, if the lifter has allowed the bar to drift forward and applies force at the beginning of the 2nd pull, the result can be coming up on the balls of the feet too early and "hipping the bar" forward and away from the lifter.

By comparing bar trajectory to video in the present study, we can see that exaggerated looping can result from this practice of hiping the bar. Even though there is a large loop, the result is that the

lifter catches the bar only slightly behind or in front of the starting position. This type of bar path requires either little or no horizontal foot movement or a marked forward hop, as it would be impossible to support the bar overhead if it were several centimeters in front of the ankle joint.

Commonly, as observed in the NACACI competition, the lifter hops too far forward or does not hop at all. In this case the bar ends up too far behind the base of support and the athlete loses the bar behind.

Our present study and the one by Reiser and Cioroslan (16) suggest that high vertical bar forces *may* overcome high horizontal displacements. This could occur in two ways: (a) forces producing a higher vertical displacement can

allow the lifter more time to move under the bar by hopping forward or backward; or (b) if the bar has been misdirected initially, applying force to change its direction to one's advantage can increase the chance of success. Otherwise, forces in the wrong direction would only serve to require more pronounced whole-body movements and stabilization efforts in order to catch the bar.

By now it would appear that a general rearward movement of the bar represents an advantageous pulling technique. While generally this may be true (15), the amount of movement and when and how this movement occurs appear to be the more important factors in bar trajectory.

For example, when pooling all attempts (n = 86), the data indicates that when lifters caught the bar farther than 20 cm behind the starting point, 85% were misses (n = 11). The average amount of displacement on the missed attempts was greater than 20 cm, compared to an average of only 10.8 cm for all successful attempts.

Additionally, if the looping was greater than the net backward horizontal displacement (DxL > DxT), then 65% missed the attempt. For an independent sample (no lifters in the group twice, n = 43), if DxT was greater than 15 cm, 65% failed and 86% of those failing looped the bar more than 15 cm.

Interestingly, if a lifter began the 2nd pull with a large Dx2 (Dx2 was more negative), the trend was to increase DxL and catch the bar farther behind the catch of most lifters. Apparently there is a region in which it is more advantageous to catch the bar, and also a position that is best for beginning the 2nd pull. The zone in which to catch the bar for the best

chance of success appears to be from the start position to ≤ 20 cm behind—and the 2nd pull position also needs to be behind the starting position.

Second, the amount of looping evident in the failed attempts suggests that, of all the variables, the degree of looping is the strongest determinant of success. This observation was further supported with a *t*-test ($p < 0.05$) comparing successful and unsuccessful attempts on the total multiplaner bar displacement (D3D) with the sample of 11 lifters who missed and then attempted the same weight.

Related to the bar path is the change in velocity during the lift. Cinematographical data (2, 9, 16) indicates that most lifters use a pattern of a first peak velocity shortly after liftoff, a slight decrease or plateau during the “double knee bend” or transition phase, and a second, higher peak velocity during the 2nd pull.

Almost all successful attempts in the present study involved a double peak in velocity. Six attempts had no identifiable velocity transition from 1st to 2nd phases, with an increasing velocity throughout the lift to a single maximum amplitude. Interestingly, this pattern (only one peak) was not consistent for all attempts in this group of lifters. A few lifters occasionally had their highest velocity (and power output) prior to the 2nd pull phase.

■ Summary

This study investigated factors that can separate successful snatches from failures. While no clearly definitive factors could be identified, three appear to be associated with successful attempts: higher vertical forces and power outputs, differences in bar trajectory (parti-

cularly less looping), and a net rearward bar displacement of ≤ 20 cm.

U.S. vs. Non-U.S. Lifters

Regardless of these results, there still remains the question of what really separates successful from unsuccessful attempts, and U.S. from non-U.S. lifters. Two key factors that might explain differences in success or failure are overhead strength during the catch phase and the bar path. Because overhead strength cannot be determined from these data, we will focus on bar path.

Observation (in person and by video) by us and personal communications from coaches from various countries suggest that the techniques of U.S. lifters often result in a markedly different bar path compared to that of lifters in other countries.

Interestingly, research from the U.S. and abroad has made use of the most current technology available at the time of data collection, and both U.S. and non-U.S. lifters have been analyzed (2, 7, 9, 13, 15, present study). It would seem logical that any pronounced differences in technique would have surfaced. However, these conclusions have not been consistently noted in the literature. It is possible that the technique (in general) of U.S. lifters has changed over the last few years.

The data from the present study suggests that absolute power and velocity of bar movement are not the main reasons for the differences between U.S. and non-U.S. lifters. Furthermore, snatches from European and Asian competitions (14, 15) reveal a general trend for a large backward movement of the bar relative to the starting position (10–20 cm).

This trend of moving the bar

markedly rearward was reported by Garhammer in 1975 during practice sessions, and later from biomechanical analysis of lifts from the 1978 world weightlifting championships, so the technique is not new (8, 9).

In our present study, this technique of pulling and jumping backward was also employed by almost all non-U.S. lifters, particularly the Canadian in the 91-kg class. Figures 1 and 2 compare the average U.S. lifter's bar path to that of European (Hiskia, V-scope files) and Canadian lifters (present study). Based on the results and observations from this study, we conclude that among the U.S. lifters:

1. U.S. lifters showed considerably more variation in bar trajectory across attempts, particularly vs. the Canadians.
2. U.S. lifters were more likely to pull forward and attempt to catch the bar forward.
3. Only one U.S. lifter who attempted to catch the bar forward of the starting position failed.
4. When the catch was ≥ 20 cm behind the starting position, there was 75% failure.
5. When the loop (DxL) was ≥ 20 cm, there was 100% failure (mean loop success = 11 cm).
6. Total multiplaner distance looped was less when successful: success = 65 cm; fail = 71 cm.
7. Larger athletes exerted greater absolute force and power.
8. The smallest athletes caught the bar 7–12 cm farther behind the larger athletes.

These observations suggest a high degree of technical variability among U.S. weightlifters, and marked differences between them

and non-U.S. lifters in bar path. The reasons for this are not clear. Perhaps there is a variable degree of knowledge and analysis skill among U.S. coaches, or an inability of U.S. lifters to produce the "correct" technique as suggested by their coach. It could also be that U.S. lifters are simply not strong enough to achieve proper positioning in various phases of the lift, particularly the liftoff.

■ Interpretation

The trajectories recorded in this study for U.S. lifters were generally quite different from those of non-U.S. lifters. Several articles (16, 17), while discussing bar direction, focus more on bar velocity as being of primary importance.

True, a certain velocity may be required to lift a given weight high enough for a lifter to catch it overhead, and a high velocity during the 1st pull might inhibit the lifter's ability to achieve the optimal 2nd pull position. But if the 1st pull velocity is too low, or the decrease in velocity during the transition is too great, the lifter then becomes solely dependent on his 2nd pull ability to make the lift.

By now it is apparent that direction of forces is a critical factor. Therefore, an important component of a successful lift is control. A lifter who is more skilled in controlling both force and bar direction will be more successful than one who may be even stronger but wastes his strength by moving the bar in undesirable directions.

From a similar perspective, it would seem logical that an athlete described as being able to overcome technical deficiencies with strength/power should be able to lift heavier weights if he improves his technique.

It is also possible that many U.S. lifters are not strong enough



Young lifter completing the pull. Notice the complete extension and strong shrug.

to achieve a proper position. Knowledgeable observers often note that a particular athlete may be able to execute lifts with relatively light weights with reasonable technique. As the weight is increased, however, the athlete's technique can change drastically.

In our opinion, the most often observed technique change occurs at the liftoff when the lifter, perhaps due to insufficient strength, allows the weight to pull him forward. Rather than moving the center of pressure on the foot back toward the heel, the center of pressure moves forward. The result is that the lifter moves onto the balls of the feet too soon and this creates marked looping. Often the attempted catch is forward of the starting position and the catch is missed.

Fatigue, which reduces the strength, power, and rate of force development, can affect bar trajectory. This was observed on video with elite junior lifters in 1989

(18). In this observation the junior squad increased their training volume by a factor of 3 for 1 week. The result was increased fatigue, reduced strength and power, and increased looping of the bar during the snatch.

Another possibility for the observed inconsistency among U.S. lifters is lack of a strong technical and strength base during the early years of training. It is possible that some athletes and coaches push too hard for early success rather than developing a superior technical and strength/anatomical foundation. While it may take longer to develop this foundation, it can serve to increase weight-lifting ability in the long run.

U.S. weightlifters, with a few exceptions, have not fared well. They have not won medals or placed among the top 5 in recent world championships or in the Olympics.

It is apparent from our study, and from comparisons of U.S.

lifters with parameters identified in other studies (2, 7-9, 13-15), that there are marked qualitative and quantitative differences between typical U.S. and non-U.S. bar trajectories.

The best U.S. totals have increased somewhat over the last few years, yet we are still unable to really compete on an international level. It would appear that this difference in international success—and technique—would stimulate an interest to discover just what it would take to make U.S. weightlifters more successful. Given these factors, coaches working with beginners, regardless of age, should:

1. Develop the proper strength/anatomical foundation; in this context the weightlifting movements by themselves are not enough.
2. Incorporate weightlifting movements into beginners' programs early and emphasize appropriate technique.
3. Get their athletes to work hard to master weightlifting techniques early in training, otherwise the chance of injury is raised and progress will be slower.
4. Become familiar with appropriate bar paths and other technical aspects in order to better evaluate lifting technique. Aspects of bar path knowledge should include 1st- and 2nd-pull movements and the ability to recognize excessive looping. ▲

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