KINEMATICS OF THE JERK FROM THE CHEST: CLUSTER ANALYSIS OF OLYMPIC-STYLE LIFTERS

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Cluster analysis (or numerical classification) is an objective data reduction technique particularly useful in identifying patterns in large, multivariate data sets (Boesch,1977). The end result is the formation of heirarchical groups based upon the degree of inter-entity resemblance. In sport biomechanics, this approach has been applied to evaluate movement patterns in a swimming start (Wilson and Howard, 1981). An alternative to clustering the movement patterns would have been to cluster the athletes according to the sequence of movement patterns.

This latter approach was selected to evaluate similarities and differences between weightlifters of vastly different performance levels as they executed the jerk portion of the clean and jerk lift. Two analyses were conducted. The first compared novice, intermediate and elite weightlifters across five "key" kinematic variables. The second compared the "optimal" temporal structure of the lift (Frolov and Levshunov,1979) with that of the novice and intermediate weightlifters.

A multivariate evaluation should facilitate an understanding of ontogenetic changes in technique. In addition, this approach may provide coaches and athletes with a generic tool for technique refinement.

MATERIALS AND METHODS

DATA COLLECTION

Forty-five jerk attempts were filmed at three U.S. Weightlifting Federation (USWF) sanctioned competitions. These athletes were classified as Master, Class 1,2,3,4 and below Class 4 by USWF criteria. All subjects signed consent forms in accordance with Purdue University's Human Subjects Research Policy. Lifts were filmed in the sagittal plane 9-10-m from the center of the weightlifting platform using a Milliken (model DBM 55) 16-mm pin registered motion picture camera outfitted with a 25-mm lens. Film speed was 30 frames sec^{-1}. Data from eleven elite athletes were from Roman and Shakirzyanov (1980 and 1978).

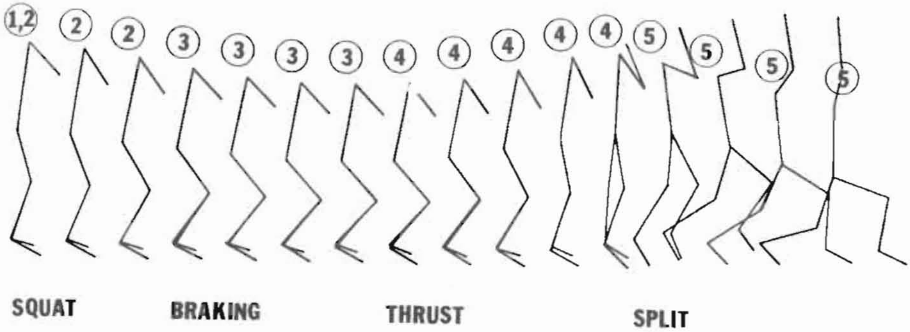

FIGURE 1. Stick-figure representation of the five phases of the jerk.

FILM ANALYSIS: DATA REDUCTION

X and Y coordinates of eleven joint centers were located from each frame of film using a Numonics digitizer (models 1220 and 224-177). The joint centers included the r/l toe, r/l ankle, r/l knee, hip, bar/hand, elbow, shoulder and head. A second order Butterworth digital filter (Patrick et al.,1980) was used to "smooth" the raw data. Digital filtering coefficients were determined during an earlier pilot study; the harmonic frequency of the jerk was best represented as a third level harmonic. Proportional and actual joint segment weights were based on Dempster (1955) and Plagenhoef et al. (1983) for males and females respectively. The barbell and hand were treated as a single segment and the weights were adjusted accordingly. Joint angles, segment velocities, etc. were calculated by a computer program modified to analyze weightlifting movements in the sagittal plane.

TABLE I. SAMPLE POPULATION CHARACTERISTICS

Classification Level (n)	Height (cm)	Bodyweight (N)	Age (years)	Number of years in competition
Females (3)	155 (152-157)	486 (387-587)	20 (15-26)	3.2 (2.5-4.0)
Below class 4 (3)	162 (150-174)	582 (481-636)	14 (12-16)	0.7 (0.5-0.8)
Class 4 (3)	164 (160-168)	557 (529-578)	17 (13-23)	0.5 (0.2-0.8)
Class 3 (5)	172 (157-180)	667 (548-803)	17 (14-21)	2.1 (0.0-4.0)
Class 2 (6)	169 (165-174)	590 (509-656)	17 (16-19)	4.8 (2.0-8.0)
Class 1 (2)	159 (158-160)	585 (534-636)	16 (16-17)	5.0 (4.0-6.0)
Master (5)	167 (162-173)	629 (587-662)	18 (17-20)	5.1 (2.0-10.0)
Elite (11)*	168 (153-186)	866 (548-1558)	N/A	N/A

Key: Mean (Range) N/A: Data not available

* Data from Roman and Shakirzyanov(1980; 1978); bodyweights are estimates based upon upper limits of the weight categories.

ANALYTIC METHODS

Variables selected for analysis were those most often provided by Roman and Shakirzyanov (1978). These included:

a. ratio of ascending to descending velocity of the barbell (AD Ratio); actual velocities could not be compared because velocities are correlated with body weight and the filmed athletes were considerably lighter than many of the elite athletes.
b. horizontal displacement of the barbell during the descending portion of the lift.
c. the depth of the descent (as percent of body height).
d. the maximum height the bar is driven overhead (as percent of body height).
e. angle of greatest knee flexion.
f. height of the athletes.

Data on the temporal (or phasic) structure of the lifts were compared with "optimal" values determined by Frolov and Levshunov (1979). Three periods, each composed of two phases, were identified (Figure 1):

Period 1: Half Squat
  Phase 1. preliminary half squat
  Phase 2. active half squat
Period 2: Jerk
  Phase 3. braking
  Phase 4. thrust
Period 3: Split
  Phase 5. nonsupport (split proper)
  Phase 6. support

Phase 1 depends upon the elastic qualities of the barbell--which is, in turn, related to the amount of weight on the bar. Since most of the non-elite lifters were not lifting weights heavy enough to gain this advantage phases 1 and 2 were combined. Phase 6 was ignored because the support phase would only be meaningful for successful attempts and unsuccessful efforts were included in this study.

BMDP program 1M, Cluster Analysis of Variables (Dixon and Brown,1979) was chosen for the analyses. The correlation coefficient, r, was the resemblance measure used in the construction of a correlation matrix. A clustering algorithm then converted the matrix into groups of larger and decreasingly similar entities. The results of the clustering procedure were expressed as a dendrogram. Two clustering strategies were selected. Group average clustering was chosen to group the athletes by kinematic variables. Group average clustering results in little distortion of the group relationships and is a widely used approach (Boesch,1977). This strategy, however, produced poorly demarcated groupings when applied to the phase duration data. Complete linkage clustering usually forms smaller groups of high similarity which are quite distinct from one another (Boesch,1977). This approach affected the shape of the phase duration clusters but had little affect on their composition.

Determination of "meaningful" clusters was aided by the construction of two-way coincidence tables comparing the ordered weightlifters by the attributes of interest (i.e., kinematic variables or phase duration). Rather than use a "fixed stopping rule" approach, in which all clusters are formed at the same similarity level, a more flexible "variable stopping rule" was employed (Boesch,1977). Once meaningful clusters were identified their mean values were presented in coincidence tables.

RESULTS AND DISCUSSION

SAMPLE POPULATION

Male athletes were generally similar in height (Table I) whereas female weightlifters were somewhat shorter. Elite weightlifters were considerably heavier than the non elite athletes, who primarily competed in the 52 to 67.5 kg (509-661 N) weight divisions. All but three of the non-elite athletes were juniors (20 years or less) whereas all of the elite athletes were likely seniors. Generally, the more years of competition the higher the classification level; no data were available quantifying the experience of the elite weightlifters.

SIMILARITY OF WEIGHTLIFTERS BY KINEMATIC VARIABLES

Six major groups (A-F) of weightlifters were identified in the dendrogram (Figure 2) depicting the similarity of weightlifters by height and the five kinematic variables. Elite weightlifters (D) were distinct from the other groups. Elite weightlifters generally had higher A:D ratios, showed less horizontal displacement, had less knee flexion and a shallower squat and did not jerk the barbell as high as most of the other groups (Table II). Master and Class I weightlifters were similar to the Elite athletes in the amount of horizontal displacement but had low A:D ratios. The optimal range for A:D ratios is 1.75 to 2.0 (Frolov and Levshunov,1979; Roman and Shakirzyanov,1978). It may be that at this stage of these weightlifter's development junior Master and Class I lifters are more limited by strength than by technique. Of the 14 lifts by these categories, only two had ascending velocities greater than 1.4 $msec^{-1}$--the lowest desirable velocity (Roman and Shakirzyanov,1978).

The remaining groups of weightlifters showed an unfavorable amount of horizontal displacement; the maximum acceptable amount is [illegible]-cm (Roman and Shakirzyanov,1978). These lifters generally squatted deeper and thrust the barbell higher than the Elite, Master and Class I athletes. A:D ratios were still below optimal but were fairly high in groups B and C--groups composed predominantly of intermediate and novice weightlifters.

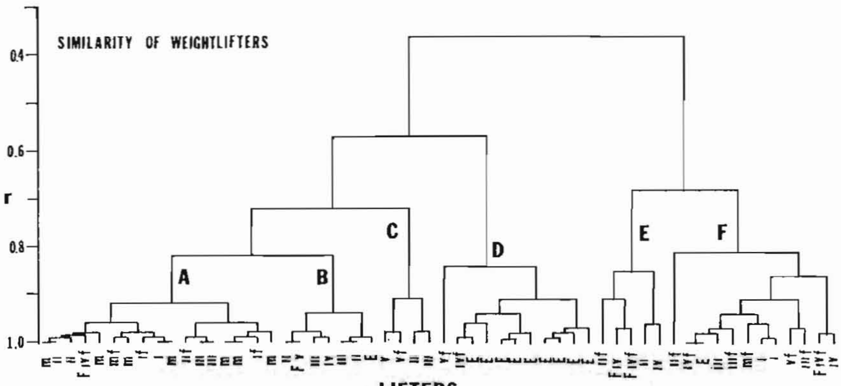

FIGURE 2. Dendrogram depicting the similarity of 56 weightliters by height and five kinematic variables describing the jerk. Groups are designated A-F. Classification levels of the weightlifters are indicated by Roman numerals (V = below class IV), M (Master) and E (Elite); F = female; f = missed attempt.

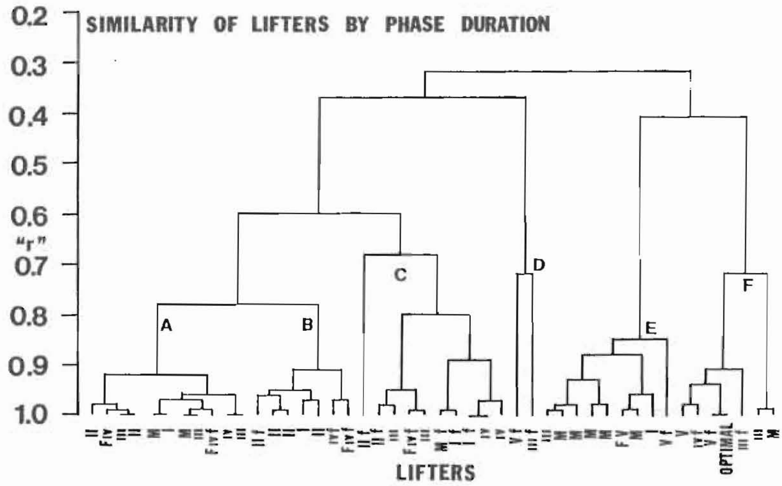

FIGURE 3. Dendrogram depicting the relationship, by phase duration of the jerk, between 45 weightlifters and the "optimal" phase duration. Weightlifter designations follow Figure 2.

TABLE II. TWO-WAY COINCIDENCE TABLE COMPARING GROUP MEANS OF WEIGHTLIFTERS X SELECTED JERK VARIABLES (CF. FIGURE 2.)

GROUP	Predominant Classification levels	Height	A:D Ratio	Horizontal Displacement	Squat (% height)	Thrust (% height)	Knee angle in squat
A	Master, Class 1	166	1.19	1.7	12.4	18.5	102
B	Class 3	167	1.53	2.7	10.0	18.5	110
C	Classes 2,3,<4	166	1.66	4.5	12.2	24.0	97
D	Elite	166	1.92	1.7	10.0	14.5	108
E	Class 4; misses by various classes	160	1.12	5.1	15.7	19.1	93
F	Class 4; misses by various classes	165	1.44	3.0	14.4	15.6	97

It appears that these weightlifters are lifting well within their strength capabilities but are limited by technique. Roman and Shakirzyanov (1978) noted that the deeper the squat the lower the velocity the barbell can attain. If the velocity is low, then the degree of thrust should also be reduced. However, six of these less-skilled weightlifters were able to thrust the barbell greater than 20% of their body height, in spite of squatting fairly deeply (Table II). Ascending velocities were still generally low, but 6 of the 31 lifts attempted by Class II and lower lifters had ascending velocities greater than 1.4 $msec^{-1}$. This is a higher percentage than was observed in the Master and Class I lifters.

TABLE III. TWO-WAY COINCIDENCE TABLE COMPARING GROUP MEANS OF WEIGHTLIFTERS X PHASE DURATION (SECS) OF THE JERK (CF. FIGURE 3.)

GROUP	Predominant classification levels	Phases 1&2: Squat	Phase 3: Braking	Phase 4: Thrust	Phase 5: Split
	OPTIMAL DURATION	.34	.14	.25	.28
A	Classes 3&4; Master & Class 2 subdominant	.23	.17	.30	.25
B	Class 2; Class 4 failures subdominant	.18	.20	.33	.23
C	Class 3; miscellaneous failures subdominant	.17	.19	.26	.27
D	Master & Class 3	.27	.12	.22	.33
E	Master; below class 4 failures subdominant	.22	.17	.24	.26
F	miscellaneous classes (Master,3,<4),failures and "optimal"	.30	.15	.27	.23

Ono et al. (1969) compared the knee angles at greatest flexion in a paired comparison of successful and unsuccessful jerks by six competitors at the 1964 Olympics. Knee flexion was greater in successful lifts than in unsuccessful attempts. They concluded that missed attempts were associated with inadequate knee flexion. In this study, a paired comparison of 7 weightlifters found no apparent difference between successful ($\bar{x}$= 101.7) and unsuccessful ($\bar{x}$= 101.5) attempts. It may be that as weightlifting has evolved since the abolition of the press lift, after the 1972 Olympics, "optimal" parameters for the execution of the jerk have changed. With the elimination of the press, there is more of a premium placed upon quickness and power than was necessary before 1973.

SIMILARITY OF WEIGHTLIFTERS BY PHASE DURATION

Six clusters (A-F) were designated in the dendrogram depicting the relationships between the 45 jerk attempts and the "optimal" phase duration (Figure 3). Unlike the previous analysis, these groups were not clearly segregated by classification level. Of the six jerks most similar to "optimal" (F), five were attempts by lifters Class III or below and three were missed attempts.

All groups had a faster squat than was desirable (Table III). On the other hand, the braking phase was generally too long. Only group D (two lifts) had a mean braking phase faster than optimal. Overall, 13 of the 45 lifts had braking phases 0.14 secs or less; seven of these jerks were by Class I and Master athletes.

The thrust phase was generally longer than optimal. Factors affecting the thrust included:

a. depth of the squat was generally too deep (Table II); therefore the thrust had to occur over a longer distance;

b. ascending velocities were generally low. For lighter lifters 1.4 $msec^{-1}$ is an acceptable velocity (Roman and Shakirzyanov,1978). However, the mean ascending velocity was 1.22 $msec^{-1}$ and only seven lifts exceeded 1.4 $msec^{-1}$.

The height of the athlete did not seem to influence the duration of the thrust since most of the lifters were of similar height (Table I).

The duration of the split was variable between groups but was generally shorter than optimal (Table III). The split phase was, however, slower in 35% of the successful jerks and 29% of the unsuccessful attempts.

Proper execution of the braking phase is the key to a successful jerk (Medvedev et al.,1982,1981; Frolov and Levshunóv,1979). The shorter this phase, the more effectively energy can be transferred to the thrust. If the velocity of the squat is too great, phases 1 and 2 will be executed too quickly. In order to brake the descent, more energy--and time--will be expended and the squat will likely be deeper than necessary. These characteristics were evident in many of the non-elite lifters studied. Because the braking phase is prolonged, the thrust is adversely affected: the delay in the switch from an eccentric to a concentric contraction diminishes the forcefulness of the thrust. The barbell is then driven over a longer distance at a suboptimal velocity.

IMPLICATIONS FOR COACHING

Several consistent distinctions between developing weightlifters and elite performers were identified which can be approached as generic problems. Virtually all of the non-elite lifters executed the squat too quickly--forcing them into a deeper squat than was necessary. This was most apparent in the class IV athletes and in the missed attempts. The rapid descent likely contributed to the increased horizontal displacement evident in all but the Class I and Master weightlifters. The fast squat also necessitated a longer than optimal braking phase. Class I and Master lifters did have braking phases close to optimal. With a longer braking phase the athletes were generally unable to exert sufficient upward force on the barbell. Ascending velocities, then, were quite low.

In spite of these errors, the barbell was often jerked higher overhead by the non-elite athletes than by the elite lifters. Missed attempts were also usually thrust higher than the 14% of bodyheight considered sufficient for a successful lift.

An area which requires additional study is the determination of optimal parameters for the split. Since most of the non-elite lifters split slower than the elite lifters, development of a faster split might allow heavier weights to be fixed overhead at a lower height.

REFERENCES

Boesch, D.F. (1977). Application of numerical classification in ecological investigations. U.S.E.P.A. Corvallis, OR. 125 p.

Dempster, W.T. (1955). Space requirements of the seated operator. WADC Technical Report, 55-159. Wright-Patterson Air Force Base, Dayton, OH.

Dixon, W.J. and M.B. Brown, eds. (1979). BMDP Biomedical Computer Programs. P-Series. Univ. California Press. Berkeley. 880 p.

Frolov, V.I. and N.P. Levshunov. (1979). The phasic structure of the jerk from the chest. Tyazahelaya Atletika. 25-28. Transl. Soviet Sports Review 1982. 17:120-124.

Medvedev, A.S., N.A. Masalgin, V.I. Frolov and A.G. Herara. (1981). The interrelationships between various parameters in jerking the barbell from the chest. Teoriya i Praktika Fizicheskoi Kultury 6:6. Transl. Soviet Sports Review. 1982. 17:134-136.

Medvedev, A.S., N.A. Masalgin, A.G. Errera and V.I. Frolov. (1982). Classification of jerk exercises in relation to the weightlifter's qualifications. Tyazahelaya Atletika. 15. Transl. Soviet Sports Review. 1983. 18:187-191.

Ono, M., M. Kubota and K. Kato. (1969). The analysis of weight-lifting movement at three kinds of events for weight-lifting participants at the Tokyo Olympic Games. Journal of Sports Medicine and Physical Fitness. 9:263-281.

Patrick, S.B., C.J. Widule and B.M. Hillberry. (1980). Digital filtering of cinematographical data. Pages 202-215. In: J. Cooper, ed. Proceedings of the CIC Biomechanics Symposium. Indiana Univ.

Plagenhoef, S., F.G. Evans and T. Abdelnour. (1983). Anatomical data for analyzing human motion. Research Quarterly for Exercise & Sport. 54:169-178.

Roman, R.A. and M.S. Shakirzyanov. (1978). The snatch, the clean and jerk. Fizkulturi i Sport Publ., Moscow. Transl. A. Charniga. 125p.

Roman, R.A. and M.S. Shakirzyanov. (1980). The clean & jerk technique of world record holder Y. Vardanyan. Tyazhelaya Atletika 9:22-26.

Wilson, B.D. and A. Howard. (1981). The use of cluster analysis in movement description and classification of the backstroke swim start. Pages 1223-1230. In: H. Matsui and K. Kobayashi, eds. Biomechanics VIII-B. Proceedings of the 8th International Congress on Biomechanics. Nagoya, Japan. Human Kinetics Publ., Champaign, Ill.

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