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Factor Analytical Study of Olympic Decathlon Data

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Basic physical fitness or motor performance functions as expressed in decathlon data are indicated through a factor analytical approach. Data from the eight Olympic decathlon championships since World War II, altogether representing 160 complete starts, are made comparable by standard score transformations within each Olympic decathlon contest. Product moment coefficients are analyzed by principal components and maximum likelihood techniques, and oblique as well as orthogonal rotations are performed. The alternative computing procedures all indicate a four-factor pattern which is interpreted in terms of running speed, explosive arm strength, running endurance, and explosive leg strength. These factors mainly cross-validate those of a previous factor analytical decathlon study and are also indicated to be more generally relevant.

Track and field athletic events have traditionally been grouped into three classes—running, jumping, and throwing. This classification suggests functional interdependence within different classes of events by reference to similarities in observed behavior characteristics.

Since the 1930s techniques of factor analysis have been applied to suggest or disclose such basic functions as expressed in the correlations of observed physical fitness or motor performance data. The fact that the number of reported studies is large and increasing suggests that this approach is relevant. Results are not unambiguous but seem to support the notion of a few rather general factors that could be further subdivided. Reviews including studies up to the early 1960s have been done by Fleishman (1964) and by Nicks and Fleishman (1962). Among more recent studies that have partly modified and elaborated on previous findings, those by Disch, Frankiewicz, and Jackson (1975), Harris (1969), Jackson (1971), Jackson and Frankiewicz (1975), and Liba (1967) should be mentioned.

After surveying 39 original factor analytical studies plus other relevant references, Fleishman (1964) suggested at least 14 different physical fitness factors. The factors most relevant to track and field athletics were running speed, running endurance, explosive leg strength (body projection), and explosive arm strength

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(object projection). These functions would be expressed most saliently in sprints, distance runs, jumping events, and throwing events, respectively.

A preliminary indication that running speed and running endurance could be considered rather independent factors was reported by Cousins (1955) and McCloy (1956). More recently Disch et al. (1975), in a factor analysis of ten running tests of various lengths within a sample of college students, very clearly demonstrated that these factors are separate.

Early studies by Rarick (1937) and Cumbee and Harris (1953) tentatively supported the existence of separate explosive strength factors for legs and arms. Some support for this notion was given more recently by Jackson (1971), Jackson and Frankiewicz (1975), and Liba (1967).

In large-scale follow-up studies on Navy recruits, not including hypothesized marker variables for running endurance, Fleishman (1963, 1964) failed to confirm separate factors of running speed, explosive leg strength, and explosive arm strength. Thus, the hypothesized markers for these factors merged into one single factor labeled explosive strength. This result contradicts the findings of Highmore (1956), who, from a factor analysis of war veterans, reported more or less dependent yet separate sprint, jumping, and throwing factors. Jackson (1971) has stated that "individual differences in running, jumping, and throwing are not dependent upon a common ability" (p. 171).

Very few factor analytical studies have been concerned exclusively with (or have even included) standard (Olympic) events of track and field athletics. In this context—with the reservation that the number of variables might be too small—decathlon data, including results from four out of ten track races and from three out of four jumping and throwing events, should constitute a relevant data base.

At least one previous factor analytical study concerned decathlon data. This is the report of Bäumler and Rieder (1972) on factor analyses proceeding from the scored decathlon points within five West German and two international elite samples. Each sample, including between 30 and 82 subjects, was separately analyzed. Varying with samples, four or five orthogonal factors were indicated. The most stable ones were labeled "Wurf" (throwing), "Sprint" (sprinting), "Sprung" (jumping), and "Laufausdauer" (running endurance).

To add to the knowledge gained through previous studies, the present study reports factor analyses of a large set of Olympic decathlon data. Resulting factors are compared not only with those indicated by Bäumler and Rieder (1972), but also with factors obtained in studies proceeding from other physical fitness or motor performance data.

Procedure

To obtain enough data to make the factor analysis meaningful (cf. Gorsuch, 1974), all athletes having scored on each event in one or more of the Olympic decathlon championships since World War II were included in the analysis. The relevant Olympic games (and numbers of complete starts indicated in parentheses) are: London 1948 (28); Helsinki 1952 (21); Melbourne 1956 (12); Rome 1960 (21); Tokyo 1964 (18); Mexico City 1968 (19); Munich 1972 (20); and Montreal 1976 (21). Altogether 160 complete starts were made by 139 athletes. One athlete (Kuznetsov, U.S.S.R.) has made four complete starts, two (Avilov, U.S.S.R. and Lespagnard, Belgium) have made three complete starts, and 14 athletes have completed two contests.

To make results from these contests comparable (and thus to make it possible to pool these results into a single data set) standard scores for each athlete and each event were computed from the raw score parameters (arithmetic means and standard deviations in cm and .1 sec) within each contest. Although this procedure might overlook some possible interaction effects such as changes in performance level resulting from changing technique (e.g., making scissors, vaulting, or flopping in the high jump) or altitude (e.g., Mexico City compared with lower-altitude arenas), it was thought that such effects would be marginal and have no affect on main results.

Correlation matrices (product moment coefficients) based on each of the ten decathlon events were computed from all 160 complete starts as well as from 139 complete starts. (In the latter case those athletes having made more than one complete start were represented by only one start, that one chosen at random.)

The correlation matrices were exploratively analyzed by alternative computing procedures (cf. Harris, 1967). Thus, the following four procedures were applied.[1]

(A) Principal (truncated) components analysis with oblique rotation according to the direct quartimin criterion (Jennrich & Sampson, 1966).
(B) Principal (truncated) components analysis with orthogonal rotation according to the varimax criterion (Kaiser, 1958).
(C) Maximum likelihood (uniqueness rescaling) analysis with oblique rotation according to the Harris-Kaiser criterion (Harris & Kaiser, 1964).
(D) Maximum likelihood (uniqueness rescaling) analysis with orthogonal rotation according to the varimax criterion (Kaiser, 1958).

Which factor solution to prefer was, except for interpretability, judged from magnitude of eigenvalues (Guttman, 1954; Kaiser, 1960), total variance proportion extracted (Gorsuch, 1974), and pattern simplicity in terms of salient and hyperplane loadings (Cattell, 1966). Salient and hyperplane loadings were defined outside the interval ±0.40 and within the interval ±0.20, respectively (Cattell, 1966; Gorsuch, 1974).

Results

The distributions of standard scores were normal or approximately normal for each of the ten decathlon events. The correlation matrices (and thus, the resulting factor matrices) computed from the data sets of 160 and 139 complete starts were nearly identical. Figures originating from the data set of 160 complete starts are reported. The corresponding correlation matrix is described in Table 1.

As seen in Table 1, all but four correlations were positive. The strongest correlation was between shotput and discus (0.73); other correlations above .50 were between 100-m and 400-m runs (0.63), 100-m and long jump (0.59), long jump and 110-m hurdles (0.52), and long jump and high jump (0.51). The four negative correlations, all involving the 1,500-m run, were close to zero.

According to the principal components analysis, the first three eigenvalues—3.78, 1.51, 1.10—were larger than unity; the fourth was 0.92 and the fifth, 0.72. The total variance proportions extracted by three, four, and five factors were 64.0%, 73.2%, and 80.4%, respectively. Corresponding variance proportions for the maximum likelihood analysis were 53.1%, 58.5%, and 62.5%. Concerning interpretability, the respective four-factor solutions—either obliquely or orthogonally rotated—were considered most meaningful. Corresponding commonality estimates, factor matrices, and separate variance contributions are summarized in Table 2. (The factors have been arranged in corresponding orders in order to facilitate comparisons.) Factor correlations for the oblique solutions are summarized in Table 3.

[1] For valuable communication on the relevance of alternative computing procedures the author is indebted to Andrew S. Jackson, University of Houston. The applied programs were BMD08M, BMD Biomedical Computer Programs and FACTOR3, Madison Academic Computing Center.

Table 1—Correlation Matrix Based on 160 Olympic Decathlon Starts

Event	Long Jump	Shot Put	High Jump	400-m Run	110-m Hurdles	Discus	Pole Vault	Javelin	1,500-m Run
100-m Run	.59	.35	.34	.63	.40	.28	.20	.11	−.07
Long Jump		.42	.51	.49	.52	.31	.36	.21	.09
Shot Put			.38	.19	.36	.73	.24	.44	−.08
High Jump				.29	.46	.27	.39	.17	.18
400-m Run					.34	.17	.23	.13	.39
110-m Hurdles						.32	.33	.18	.00
Discus							.24	.34	−.02
Pole Vault								.24	.17
Javelin									−.00

From Table 2 it is obvious that the alternative procedures—A, B, C, D—mutually support the validity of a commonly indicated factor pattern. Thus, the identification of marker variables and pattern simplicity correspond very closely.

All four procedures identify 100-m run and 400-m run as marker variables of Factor I, shotput, discus, and javelin as markers of Factor II, 1500-m run as marker of Factor III, and long jump, high jump, 110-m hurdles, and pole vault as markers of Factor IV. For procedures A, B, and D long jump and 400-m run are, in addition, saliently loaded on Factors I and III, respectively, and for procedure B 110-m hurdles also is saliently loaded on Factor I. The presented factors are consecutively interpreted in terms of *running speed* (Factor I), *explosive arm strength* or object projection (Factor II), *running endurance* (Factor III), and *explosive leg strength* or body projection (Factor IV).

Consistent with what has been said above, the distribution of salient loadings is one per variable for procedure C. For procedures A and D eight variables have one salient loading and two variables have two. For procedure B seven variables are saliently loaded on one factor and three on two factors. The proportions of hyperplane loadings are 65.0%, 57.5%, 67.5%, and 57.5% for procedures A, B, C, and D, respectively. These percentages should be compared with the maximum proportion of hyperplane loadings when the distribution of saliency is one per variable. For a four-factor solution this figure is 75.0%.

Table 2 shows that average commonalities and total variance contributions are larger for procedures A and B than for procedures C and D. This should mainly be a consequence of the fact that principal components analysis (contrary to maximum likelihood analysis) proceeds from unities as diagonal elements in the correlation matrix.

For procedures A and B the commonalities vary from .58 for javelin to .88 for 1,500-m run, while the commonalities according to procedures C and D vary from .22 for javelin to .79 for shotput. Provided that true variance proportions (reliabilities) are of about the same size for all variables, this means that javelin (according to this study) should be the most specific of the decathlon events. This is further supported by all four five-factor solutions in which javelin, separated from the previous explosive arm strength factor, is the only marker of the fifth factor. Also, it might be relevant to note that the markers of the explosive leg strength factor (for procedures C and D especially pole vault) should have relatively large specific variance proportions.

Each of the running speed, explosive arm strength, and explosive leg strength factors extracts about 20% of the total variance according to procedures A and B and about 16% according to procedures C and D. This indicates that these three factors should be about equally important for the decathlon championships. The

Table 2—Estimated Commonalities, Factor Matrices, and Separate Total Variance Contributions for Four Alternative Computing Procedures. (Salient loadings are italicized.)

	Com-mon-ality		Factor I				Factor II				Factor III				Factor IV			
Event	AB	CD	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
100-m Run	.84	.78	*.87*	*.88*	*.85*	*.81*	.06	.13	−.05	.16	−.15	−.11	−.28	−.15	.04	.16	.06	.28
Long Jump	.70	.64	*.53*	*.63*	.29	*.47*	.08	.20	−.03	.21	−.05	−.00	−.08	.00	*.45*	*.51*	*.60*	*.61*
Shot Put	.81	.79	.13	.25	.03	.15	*.82*	*.82*	*.82*	*.83*	−.16	−.15	−.10	−.10	.06	.22	.06	.27
High Jump	.64	.55	.08	.24	−.14	.14	.00	.14	−.01	.20	−.01	.04	.07	.11	*.77*	*.75*	*.82*	*.69*
400-m Run	.87	.78	*.83*	*.80*	*.87*	*.76*	.03	.07	−.00	.07	*.44*	*.47*	.29	*.41*	.02	.11	−.09	.20
110-m Hurdles	.61	.44	.26	*.40*	.07	.28	.02	.16	.01	.22	−.20	−.15	−.10	−.05	*.62*	*.63*	*.60*	*.55*
Discus	.72	.70	.09	.19	.05	.12	*.82*	*.81*	*.86*	*.81*	−.08	−.08	−.01	−.02	.01	.15	−.10	.15
Pole Vault	.67	.29	−.21	−.04	−.12	.07	.06	.18	.05	.17	.19	.23	.14	.16	*.81*	*.76*	*.56*	*.48*
Javelin	.58	.22	−.13	−.05	−.04	.03	*.77*	*.74*	*.46*	*.44*	.15	.14	.04	.04	−.01	.11	.06	.16
1,500-m Run	.88	.67	.10	.05	.06	.04	−.03	−.04	.07	−.05	*.93*	*.93*	*.82*	*.81*	.07	.09	.03	.12
Separate Percent of Total Variance			18.9	21.3	16.0	16.0	19.5	20.2	16.4	17.3	12.1	12.3	8.8	9.0	18.4	19.4	17.3	16.3

Table 3—Factor Correlations for Two Alternative Computing Procedures

	Procedure A			Procedure C		
Factor	II	III	IV	II	III	IV
I	.21	.03	.35	.35	.10	.65
II		−.03	.37		−.15	.56
III			.06			.07

running endurance factor is less important yet extracts as much as 12% and 9%, respectively, of the total variance.

As can be seen from Table 3 the strongest factor correlations for the oblique solutions are those between running speed and explosive leg strength and between explosive arm strength and explosive leg strength. Also, running speed and explosive arm strength seem moderately correlated. The only negative correlation, that between explosive arm strength and running endurance, is close to zero. Generally, procedure A results in weaker correlations than procedure C.

To sum up this section, the alternative computing procedures result in four-factor solutions that are very consistent with each other. The oblique solutions might be preferred because of somewhat simpler factor patterns.

Discussion

For at least two reasons—the very high performance level of observed subjects and the relatively small number of marker variables—the appropriateness of generalizing from these findings could be questioned. The findings of studies reported earlier in this paper, however, add support to the general relevance of factors indicated in the present study.

Concerning the number of stable factors and the identification of markers, this study mainly cross-validates that of Bäumler and Rieder (1972). In addition, the findings that javelin and the explosive leg strength markers have the smallest communalities are consistent with their results. However, while they found that the "Sprung" (jumping) factor did not extract (much) more variance than the "Laufausdauer" (running endurance) factor but that each of the "Sprint" (sprinting) and "Wurf" (throwing) factors extracted up to about twice as much, the present study found that the explosive leg strength factor extracts about the same total variance proportion as that of the running speed and explosive arm strength factors.

It is obvious that the relevance of the factors here indicated also gains substantial support from previous factor analyses proceeding from other subject populations and variables, especially those by Jackson and co-workers (Disch et al., 1975; Jackson, 1971; Jackson & Frankiewicz, 1975).

The basic functions indicated in this study are mainly consistent with the traditional classification of track and field athletics referred to initially. One elaboration is that this analysis, as others, indicates the existence of two independent running factors. Another difference is that this analysis, as did most of Bäumler and Rieder's (1972), identifies 110-m hurdles as a marker of primarily explosive leg strength while long jump, according to the principal components analysis, is primarily a marker of running speed. From the traditional classification the reversed relationship might have been expected. It should, however, be noticed that both events include running and jumping phases, which is also reflected in the factor matrices (Table 2).

Finally, such basic functions as are here suggested by factor analysis reasonably have correlates in different physical processes and structures. For example, running endurance has been related to maximum oxygen uptake (see Disch et al., 1975, for a brief summary) and to percentage of type I (slow) fibres in skeletal muscle (see, for example, Hedberg & Jansson, 1976). In this respect, findings of factor analytical and physiological or biochemical studies could be interdependently validated or modified.

Conclusions

According to the factor analytical findings presented here, four basic functions—primarily expressed in sprints, throwing events, distance runs, and jumping events—are indicated to be the most relevant for individual differences in Olympic decathlon performances. Mainly by reference to the terminology used by Fleishman (1964) and by Nicks and Fleishman (1962), these four functions are labeled running speed, explosive arm strength, running endurance, and explosive leg strength. By comparisons with other factor analytical studies proceeding from both decathlon data and other physical fitness or motor performance data, the relevance of the referred basic functions is indicated to be rather general.

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