WHAT DO PHYSICAL FITNESS TESTS MEASURE?— A REVIEW OF FACTOR ANALYTIC STUDIES

by

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FORWARD

The funds for this study were provided under Contract Nonr 609(32) between Yale University and the Office of Naval Research. This report describes the first in a series of studies under the general project title "The Development of Criteria of Physical Proficiency".

Work under this project is an outgrowth of my earlier interest in the structure of human perceptual-motor abilities. Athletic performance is certainly a kind of motor skill, but the component abilities contributing to such performance are not well understood. Once these components are identified and defined, a comprehensive battery of tests might be developed to measure them. This report represents the preliminary groundwork toward these objectives.

This review was carried out by Dr. Delmer C. Nicks in the summer of 1958, while he was Research Associate on this project at Yale University. Dr. Nicks continued his association with the project when he returned to San Fernando Valley State College, Northridge, California, where he was Assistant Professor of Psychology. His sudden and tragic death in February, 1959, at the age of 29, saddened his many friends, students, and colleagues and removed from the scene one of our most promising, young, experimental psychologists.

I have undertaken to complete this review and to write this report from the notes, cards, and early drafts left by Dr. Nicks. The difficulty in assembling all the materials from his files in California and here accounts, in part, for the delay in the appearance of the report. For the assistance provided in this matter I would like to express my appreciation to Mr. Paul Thomas and Mr. Phil Munroe of San Fernando Valley State College, and especially to Dr. Nicks' wife, Mrs. Ruth Nicks.

Mr. Elmar Kremer, research assistant on this project, provided valuable help in the conduct of this review.

Appreciation for their work in connection with the contract is extended to Dr. D. D. Smith, Head, Psychological Sciences Division, and to Mr. John Nagay, Assistant Head, Personnel and Training Branch, in the Office of Naval Research.

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There is, today, considerable interest in developing and maintaining the physical proficiency of our manpower resources. Programs of physical education are an integral part of curricula in public and private schools, colleges and universities. Such programs extend through all levels of training in the Armed Forces and to their military academies. It is possible that individual students spend more time in physical education programs than in any other single program during their school careers.

In 1956 President Eisenhower appointed a special committee on physical education to study and advise him on the problem. Practically every leading magazine[1], during the past few years, has carried a feature story pointing up the relatively low level of performance of American youth on physical proficiency standards. One reason for the increasing public and official concern has been a series of studies which report that European youth is far superior to American youth in general physical proficiency (Kraus and Hirschland, 1953, 1954). These conclusions are based on six tests (the "Kraus-Weber Tests"). There is ample evidence however, that these tests sample only two or three of many ability factors in physical proficiency. In one study, Hempel and Fleishman (1955) identified eight factors and there are indications from other research that still additional factors must be considered in any comprehensive evaluation of physical proficiency. Clearly, we need to know what physical proficiency factors need to be assessed and we need to know what tests are the best measures of these factors.

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[1] For example, "The Report that Shocked the President", Sports Illustrated, Aug. 1955; "Is American Youth Physically Fit?", U. S. News and World Report, Aug., 1957.

A direct approach to this problem is a correlational approach in which large numbers of tests are given the same subjects. The assumption is that tests which correlate with each other measure the same factors and tests which are uncorrelated measure different factors. The mathematical technique of factor analysis (see e.g. Thurstone, 1947; or Fruchter, 1954) is applied to the correlations to isolate the common factors and to assist in their description and interpretation.

PURPOSE

This report presents a critical review and integration of previous factor analysis studies in this area. The review indicates the range of factors which have been identified as well as the kinds of tests which seem to measure them. It is hoped that this review will provide a) a framework for subsequent research into the dimensions of physical proficiency and b) a rationale for the development of a comprehensive battery of physical proficiency measures. It represents a first step in a series of studies on these problems.

Nature and limitations of the review

Most of the studies reviewed are in the physical education literature. Many of these studies are concerned with building and assessing short batteries of tests which will correlate with a longer, more comprehensive, battery of tests. Thus, they are more concerned with increasing the efficiency of the testing process than with identifying basic abilities. This goal, however desirable, results in serious methodological problems when factor analysis is applied. For example, factor analyses in this literature often include as variables a number of composite scores from short batteries of tests. In some articles over half the variables are of this nature. Frequently, these analyses include course grades as variables in order to determine what factors contribute to success in the course. Finally, many of the individual tests are themselves exceedingly complex. It can be seen why factor resolution, in many cases, has been difficult to achieve in these studies.

Other difficulties stem from the analyses themselves. In several studies factor extraction and/or factor rotations were stopped too soon. This compounded the difficulty of comparing factors across studies, except in the area of strength tests, which was the best defined. In some studies it appeared that an oblique or hierarchical factor solution might have been more appropriate for the data. This was particularly true of analyses made within a highly delimited area where all of the tests were highly intercorrelated (for example, dynamometer strength tests). In several cases, we were able to extract additional factors or make additional rotations of the original author's data in attempts to improve factor resolution and clarify interpretations.

PROCEDURE

A card file of factors was made to include a card for every factor in each study reviewed. Each card contained the test loadings for that factor. Similar factors were then sorted into piles as an aid in comparing factors. Inspection of the tests in common made it possible to identify some factors with different names as essentially the same. In some cases, factors given the same name were really quite different. Consequently, in the review to follow, factors sometimes were given names other than those used by the original investigator. For the most part, however, original factor names held up across studies. Where different factor names were provided by different authors, we used the name which we felt was most descriptive operationally.

FACTOR AREAS

It should be stressed that, despite the cautions and difficulties described above, there was considerable consistency in a number of the factors which emerged. Furthermore, these seem to fall into several broad areas of ability.

We will describe these factors, point out the tests which seem to measure them, and discuss some questions raised by these findings.

STRENGTH AREA

By far the most clearly defined area in the factor analysis literature is the area of "strength". When the intercorrelations among tests of strength are factored three broad factors emerge repeatedly. These factors are Explosive Strength, Dynamic Strength and Static Strength. There appears to be some correlation between these factors, though the correlation is not high. In studies of physical fitness tests where these three factors did not emerge, there was usually a "general strength" factor. This occurred when there were not enough strength tests to define the three separate factors.

Let us examine these three factors more thoroughly.

Explosive Strength: This factor was identified more often than any of the others (see e.g. Brogden, Burke, and Lubin, 1952; Coleman, 1940; Cumbee and Harris, 1953; Harris, 1937; Hempel and Fleishman, 1955; Hutto, 1938; McGraw, 1949; Rarick, 1937; Shapiro, 1947). In addition, analyses by Carpenter (1941), Cousins (1955), Highmore (1956), Larson (1941), McCloy (1940, 1956), Phillips (1949), and Seashore (1942) yielded factors which can be interpreted as Explosive Strength. This factor appears to emphasize the ability to exert maximum energy in one explosive act. It has been called Energy Mobilization or Power or Velocity in some studies. The purest tests of this factor include standing broad jump, vertical jump, and medicine ball put. Shot put has a loading on this factor almost as high as medicine ball put, but also loads significantly on other strength factors. The common feature of tests of Explosive Strength is that one is required to jump or to project oneself or to project some object as far or as high as possible. The factor is distinguished from other strength factors in requiring one short burst of effort, rather than continuous stress or repeated exertion.

Short runs, dodging runs, shuttle runs, etc. often have appreciable loadings on this factor. This is probably due to the push-off type motions involved in many of these tasks. It seems reasonable that in these shorter sprints, a runner's time is increasingly attributable to the speed with which the runner can "get off the blocks". This is consistent with our notion of the Explosive Strength factor.

There is some evidence that there are separate, though highly correlated Explosive Strength factors for arms and legs (Cumbee and Harris, 1953; Rarick, 1937). These factors appeared separately, together with a general Explosive Strength factor, in one of the most careful hierarchical solutions (Brogden, Burke, and Lubin, 1952) and in a recent unpublished study factored by Nicks. The Explosive Strength-Arm factor was defined by throws, puts, etc. while the Explosive Strength-Leg factor was defined by various jump tasks.

Dynamic Strength: This factor has appeared in the literature almost as frequently as the preceeding factor (Brogden, Burke, and Lubin, 1952; Cousins, 1955; Cumbee and Harris, 1953; Hempel and Fleishman, 1955; Larson, 1940, 1941; McCloy, 1956; McCraw, 1949; Metheny, 1938; Seashore, 1942; Shapiro, 1947). It sometimes has been called Velocity or Speed, but these names are somewhat misleading. Dynamic Strength seems to involve the strength of muscles in the limbs in moving or supporting the weight of the body repeatedly over a given period of time. The best tests for this factor seem to be pull-ups (chins), rope climb, and dips. Dips require the subject to suspend himself between parallel bars with arms rigid; the subject lets himself down and pulls himself up as many times as possible. A critical aspect of this factor appears to be the requirement that the muscular force must be repeated as many times as possible, with a consequent progressive decrement in the force which can be exerted. Individual differences in this ability are largely a function of how many repetitions can be made.

Thus far, most of the tests defining this factor involve arm muscles. There is some evidence, however, for a separate Dynamic Strength factor involving the trunk muscles (Hempel and Fleishman, 1955; Phillips, 1949). Sit-ups, leg lifts, and push-ups are examples of tests loading on this factor. There is the further possibility of separate arm and leg factors, although separate factors were not isolated in any of the studies reviewed. The reason for this may be that none of these studies included any tests that could be expected to define a leg factor. The appearance of moderate loadings for short sprints on this factor does suggest the possibility of a separate though correlated leg factor (e.g. McCloy, 1956). It would be a straightforward experiment to check this hypothesis. One study found separate factors for arm extensors and arm flexors (Brogden, Burke, and Lubin, 1952). However, these factors were very highly correlated. In any case, there appears to be a cluster of correlated sub-factors in this area which need more precise definition.

Static Strength: This third, broad strength factor has emerged clearly in several studies (Carpenter, 1941; Cureton, 1947; Harris, 1937; Larson, 1940, 1941; Phillips, 1949; Rarick, 1937; and Sills, 1950). The best tests of Static Strength appear to require an exertion of a maximum force for a brief period of time where the force here is exerted continuously up to a maximum. Typically, the force is exerted against a fairly immovable object, such as a dynamometer. This contrasts with Explosive and Dynamic Strength where there is substantial movement of the body or limbs. Furthermore, in Dynamic Strength, the force must be repeated in successive movements and in Explosive strength the strain on the muscle is not continuous. Tests which have defined Static Strength include dynamometrical tests applied to hand grip, as well as to arm, back, and leg muscles.

In an unpublished study, Nicks factored a small correlation matrix of dynamometrical tests provided by McHone, Tompkin, and Davis (1952). While he found some evidence for separate factors representing various functional parts of the body, most of the tests turned out to be complex factorially and the factors were not well differentiated. It appears that it is probably not worthwhile to try to isolate a number of separate factors in the Static Strength area. It is of interest to note that before the application of factor analysis to these problems, test batteries of physical proficiency often placed considerable emphasis on different tests of static strength. The lack of correlation of Static Strength with the Dynamic and Explosive Strength factors, together with the greater practical implications of these latter factors for significant human activities, would argue against such overemphasis on tests of Static Strength.

FLEXIBILITY - SPEED AREA

Another ability area which seems distinct from Strength has been termed Flexibility. Tests of this factor appear to require the muscles involved to endure strain or distortion, with some emphasis on rapid recovery from this strain allowing an immediate repetition of the movement. There is evidence for separate Flexibility factors for the limbs and for the trunk. For example, Hempel and Fleishman (1955) found tests of kicking height and leg bends on a "Limb Flexibility" factor distinct from a "Trunk Flexibility" factor.

Extent Flexibility: An alternative breakdown of factors in this area is "Extent Flexibility" versus "Dynamic Flexibility". The Hempel and Fleishman factors may be interpreted as Extent Flexibility. Tests of Extent Flexibility emphasize the ability to move or stretch the body, or some part thereof, as far as possible in various directions. For example, a person who could perform yoga exercizes would score extremely high on this factor.

Dynamic Flexibility: Tests of the Dynamic Flexibility factor involve the ability to make repeated flexing or stretching movements (where the extent of the movements is either short or long). Examples of such performances are squat twist and deep knee bends. This section has been called "Flexibility - Speed" because analyses of physical fitness tests frequently reveal a correlated cluster of factors which emphasize both flexibility and speed of bodily movements and it is difficult to separate them. Thus, factors called "Speed of Limb Movement", "Speed of Change of Direction" sometimes emerge in analyses of such tests (Brogden, Burke, and Lubin, 1952; Cumbee, 1954, Cumbee, Meyer, and Petersen 1957). One hypothesis is that a hierarchical factor structure might best describe this area. The most general factor would be a "General Flexibility - Speed" factor. Contributing to this would be two broad second order factors, Extent Flexibility and Dynamic Flexibility. Dynamic Flexibility which we have defined above, may be the same as a Speed of Bodily Movement factor identified elsewhere. Finally, there would be fairly narrow factors such as Speed of Limb Movement, Speed of Change of Direction, and, perhaps, a Run factor. It is possible that some of these might break up into specific limb factors. Figure 1 diagrams the structure which might be found.

Some support for this interpretation is found in an unpublished analysis by Nicks of data provided from McHone, Tompkin, and Davis (1951). And these factors have been identified in separate analyses by others. For the present, we will give the tentative definitions of the factors which have been found in the area we call "Dynamic Flexibility". On occasion, the term "Velocity" has been applied to one or all of these factors in the previous literature.

Speed of Change of Direction. This factor is defined by tests in which the subject must quickly change direction, usually while running (Brogden, Burke, and Lubin, 1952; Cumbee, 1957; Cumbee and Harris, 1953; Larson, 1941; Phillips, 1949; Shapiro, 1947; Wendler, 1938). Shuttle runs, dodging runs, potato races, load highly on this factor. Some investigators have preferred the name "agility"

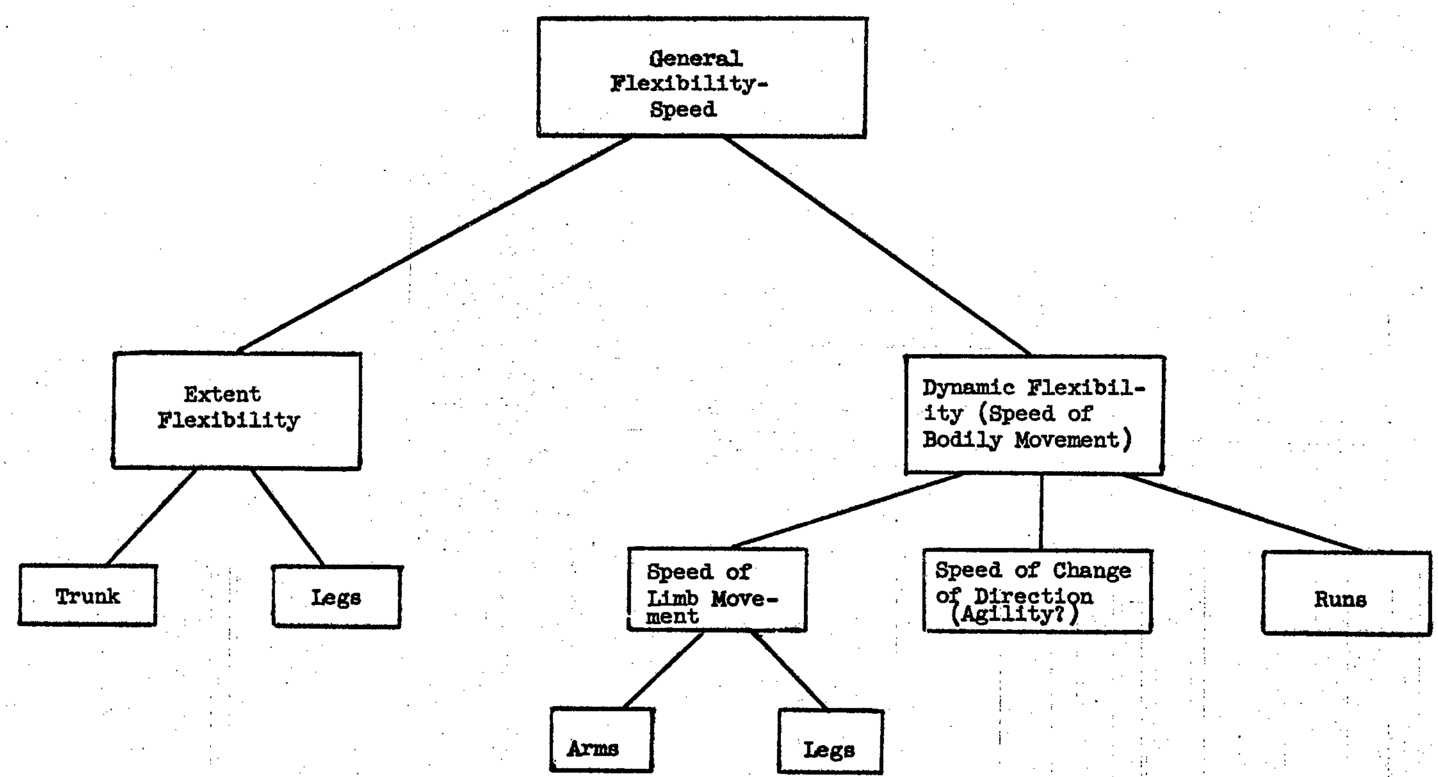

Figure 1

A possible heirarchical factor structure describing the Flexibility-Speed area.

(e.g. Cumbee and Harris, 1953; Larson, 1941; McCloy, 1940; McCloy and Young, 1954; Shapiro, 1947). The relation of this factor to agility tests and to runs tests needs to be established.

Running Speed. This factor has been identified repeatedly as common to short and long dashes (Brogden, Burke, and Lubin, 1952; Cousins, 1955; Highmore, 1956; McCloy, 1956; Sills, 1950; and Wendler, 1938). There is evidence that this factor correlates with the Dynamic Strength factor previously described. There is some evidence that run tests also correlate with endurance factors. For the present we include it here on a logical basis, although its status is not clear. A question that needs answering, for example, is whether tests like Shuttle Run (which loads on a Speed of Change of Direction factor) measures anything different or additional to straight long or short dashes. The literature treats them as measures of separate abilities, but future research will clarify this practice.

Speed of Limb Movement. This is the ability to move the arms or legs as rapidly as possible, where skill is not involved. Thus, a Speed of Arm Movement factor has been found (Cumbee, 1953, Cumbee, Meyer and Petersen 1957; Fleishman, 1954, 1958; Fleishman and Hempel, 1954, 1956) in tasks requiring the subject to strike two plates with a stylus, or to break photoelectric beams with rapid arm movements.

BALANCE AREA

The factor structure in this area is not well defined since very few studies have included more than one or two balance tests. Not many tests of balancing ability have been developed. However, the studies which did include some balance tests furnish some suggestions of factors that might appear here (Bass, 1939; Carpenter, 1941; Cumbee, 1953, Cumbee, Meyer and Petersen, 1957; Hempel and Fleishman, 1955). There is evidence for separate static and dynamic balance factors. These have been called Equilibrium Balance and Performance Balance (Hempel and Fleishman, 1955). There is also some indication that balancing ability may be related to whether the eyes are open or not (Bass, 1939). This should be quite easy to test. The relationship of these to a "Kinesthetic Discrimination" factor measured by "tilting chair" tests (Fleishman, 1954) needs to be determined. Finally, one study (Cumbee, Meyer, and Petersen 1957) isolated a "Balancing Objects" factor in each of two studies. The definitions of the balance factors found by our review, follow.

Static Balance: This factor seems to represent the ability to maintain bodily equilibrium in some fixed position. Often this position may be an unusual one. Tests requiring the subject to stand on one foot or to stand on a rail have loaded on this factor.

Dynamic Balance: Tests of this factor require the subject to maintain balance while performing some task (for example rail walking). It is likely that good tests of this factor might require the subject to balance himself on a very unstable object like a large ball.

Balancing Objects: The name of this factor is self-explanatory. Tests of this factor would involve balancing a yardstick on the end of the finger, or a ball on the back of the hand, etc.

COORDINATION AREA

An area of physical proficiency which would appear distinct from strength, speed, flexibility, and the other factors mentioned, and important in its own right, is that of coordination. Yet correlational studies have failed to show up an ability which could be labled with confidence as "general coordination". An additional question of interest is whether there are several types of coordination.

Multiple Limb Coordination: Fleishman (1956, 1958) Fleishman and Hempel (1956), and Parker and Fleishman (1959) have identified a factor which they call "Multiple Limb Coordination" in analyses of perceptual-motor abilities. This factor is common to psychomotor tasks in which the subject must coordinate the simultaneous movements of two hands, two feet, or hands and feet in operating various devices. Shapiro (1947) also found such a factor in psychomotor tasks. However, tests of this factor do not correlate very much with physical proficiency types of tasks (Adams, 1953; Shapiro, 1947). So, it appears that the kind of coordination emphasizing simultaneous use of several limbs in operating equipment is not the same kind of coordination as might be involved in athletic type tasks. In Fleishman's studies with psychomotor devices the subject is seated or standing in one place and is not required to move his whole body. Perhaps, the critical distinction is that movement of the whole body is not involved in the kinds of tasks which appear on the "Multiple Limb Coordination" factor.

Gross Body Coordination: Cumbee (1953), Cureton (1947), Hempel and Fleishman (1955), Larson (1941), and Wendell (1938) did identify a factor they called "Gross Body Coordination", which did seem to emphasize more gross activity of the whole body (e.g. hurdling and jumping tasks). Perhaps, this is the same factor which others have called "Agility". The question is not yet answered, but is worth checking in future studies.

This is not to say that several coordination factors have not been identified in the physical fitness area. Such factors have been found but are poorly defined. For example, a general factor often labeled "Gross Body Coordination" can be expected to appear when a number of complex sports skill tests (e.g. ball catching, soccer kicking) are included in a larger battery (e.g. Cumbee, 1953, 1957; Wendell, 1938). However, this tells us little about the precise nature of this factor or its possible components. The distinction between this factor and one called "Motor Educability" (e.g. Larson, 1941; McCloy, 1938; Metheney, 1938; Wendler, 1938) is not clear. Some (e.g. McCloy, 1938) have viewed this factor as representing a kind of physical fitness IQ general to tasks requiring large-muscle coordination. The best measures of this factor are the Brace Test and the Johnson Test. Both of these are composites of many subtests emphasizing tumbling, hops, stunts, balance, etc. It is possible that this factor taps some kind of "understanding of what has to be done" in a complex skilled motor performance. However, it is likely that the "Motor Educability" factor would break up into components in suitably designed studies, as McCloy, himself, implies (McCloy, 1954).

The findings of Fleishman on the definition of the Multiple Limb Coordination factor suggest that this ability depends on central or cortical nervous system activity. This inference is made from the fact that people who do well on two-hand coordination tasks, also do well on foot-hand, and two feet coordination tasks. For example, no separate factor confined to two hand activity was found. The generality of the "Gross Body Coordination" factor, whatever its precise definition, would seem to imply an emphasis on central factors independent of body members or particular muscle groups. If this is true, then it will be difficult to develop pure tests of this kind of coordination, just as it has been difficult to develop pure tests of Multiple Limb Coordination. However, future studies should be directed at a better definition of this ability area with the subsequent attempts to develop some tests which emphasize coordination and minimize strength, flexibility, balance, etc. Of course, it may turn out that the essence of coordination is the ability to integrate the separate abilities in a complex task. Analyses of test batteries containing "coordination" tests varied in specific ways should clarify these questions.

ENDURANCE AREA

Several studies with physical fitness tests have isolated a factor labled Endurance (Brogden, Burke, and Lubin, 1952; McCloy, 1956) or one which could be so interpreted (Cousins, 1955). McCloy (1956) identified several different endurance factors, but on close inspection, two of these turn out to be more like our definitions of Dynamic Strength and Explosive Strength; his third factor may be Endurance. In a typical case (McCloy, 1956) the factor was defined by long runs and "drop-off" scores. The "drop-off" score was computed as a ratio of an individual's speed for long and short runs; the assumption is that the greater the difference between long and short run performance, the poorer the "endurance". Of course, the inclusion of such scores in the same analyses with the long run scores would yield a spurious factor common to these scores. Thus, the factor labeled "endurance" in these studies may be nothing more than a specific "run factor".

However, there is some evidence that an endurance factor may extend beyond run tests to other tests requiring subjects to perform over time. Thus, tests such as dips and pull-ups, when scored in terms of "number completed" may load on a factor with running tests. Whether this means that long runs involve limb strength or that both long runs and certain strength tests depend on a separate "endurance" factor remains to be shown. It would be possible to explore this by giving some strength tests as "endurance" tests (e.g. do as many pull-ups as possible) and as timed tests (do as many as you can in 30 seconds) and examining their relationships to other endurance type tests (e.g. long runs). Is there any variance besides strength, which we might label endurance, in the first type of pull-up test which is not in the timed version?

In a recent unpublished study by Nicks, an endurance factor was tentatively identified as common to "leg raiser" and "bent arm hang" tests. The first test requires the subject to lie on his back and hold his legs 12" off the ground for as long as possible. In the second test the subject pulls himself up until his eyebrows are even with the chinning bar; he holds this position as long as he can. This factor appeared separate from a Dynamic Strength factor defined by a traditional "pull-up" test and a "dips" test, but it was highly correlated with it.

The question to be answered is not whether "endurance" is important in such tests, but whether it is necessary to postulate a separate "endurance" ability over and above the strength factors previously described. Such an ability, for example, might emphasize the capacity to maintain maximal effort over time. In our present state of knowledge we should allow for this possibility in future studies. Of special interest is the relationship of endurance to the strength area and the possibility that several endurance factors may exist. In the former instance it will be recalled that an alternative name for the "Explosive Strength" factor has been the name "Energy Mobilization".

CONCLUSION

This review has described fourteen factors of physical proficiency identified from previous research. Other possible factors which might be discovered were also described. A number of questions were raised regarding the structure of skill in this area and suggestions were made for future studies to answer these questions. Several things are clear. There is no such thing as general "physical proficiency". The problem is a multidimensional one. It is also clear that previous studies comparing American youth with youth of other countries have assessed only a small number of the factors already identified. From the foregoing discussion, for example, it would appear that the Kraus-Weber tests measure mainly the Extent Flexibility (Trunk) and Dynamic Strength (Trunk) factors.

As a follow-up to this review, several large scale studies will be conducted. The attempt will be made to include representative measures of these factors and administer them to large samples of subjects. The objective is to answer some of the questions raised about the structure of physical proficiency, to clarify some of the factor definitions, and to identify new factors which might emerge. Eventually, we hope to develop a battery of basic reference tests which will provide comprehensive coverage of abilities in this area. Such measures would also allow an assessment of the relative contributions of the component abilities to a variety of different, more complex, athletic performances.

In the meantime, Appendix A presents an outline and description of tests which might be included in such studies. Some are well known tests but others are new ideas. This outline also provides an interim report of what abilities such tests probably measure.

APPENDIX A

Tests Classified by Factor

The tests will be classified by factor area. It should be stressed that in many cases these are hypothesized areas (see text) and in other cases the tests are new and their factor content unknown. Furthermore, for newer tests considerable pretesting needs to be done before precise administrative conditions can be specified. This list is to be regarded as a starting point for definitive studies in which these tests are administered together to the same subjects and their empirical relationships determined. However, for the time being this list may be helpful to individuals interested in a comprehensive coverage of abilities in this area, based on current knowledge. A reading of the text will indicate the degree of confidence to be placed on the different factor areas described.

In some cases the reader may recognize a familiar test which has been changed in some way. This does not indicate a lack of standardization but rather a suggestion for "purifying" such tests to measure the indicated factor. For example, the Vertical Jump Test is similar to the Sargent Jump Test. However, in the Sargent test the subject jumps and stretches his arm as high as he can. We require the subject to keep his arms down in order to minimize a possible Extent Flexibility factor while maximizing the Explosive Strength-Leg factor.

The first 32 tests provide the basis for a single factor analysis study of Strength-Endurance tests. The remaining tests could comprise a single study in an area loosely termed, Speed-Flexibility-Coordination. Certain tests should remain common to both studies. For example, "run" tests would appear to be needed in both studies to provide answers to a number of questions raised in the preceding review.

Explosive Strength - Legs

1. Vertical Jump. The subject jumps as high as possible, without raising arms above the shoulders at any time. He may be allowed a few practice jumps before the actual test jumps. His score is the best of three jumps. The score is the difference between the subject's standing height and the top of his head at the highest point of jump. One of the simpler ways to measure this is for an observer to stand on a bench with a light rod. He touches the wall at the proper point after each jump to record the height. The rod may be held lightly on the S's head if necessary. Observers should practice this before actually scoring the test.

2. Standing Broad Jump. The subject stands with his toes touching the start line which can be the edge of a mat or a line of the floor. He then jumps as far as possible with his hands at his side without falling backwards onto his hands. If he falls backwards the jump does not count. His score is the distance from the start line to the heel of the closest foot at the time of impact. The best of three jumps is recorded.

Explosive Strength - Arms

3. Sitting Medicine Ball Push. The subject sits on the floor with his legs spread out in front of his body. He then holds a medicine ball between his palms and throws it as far as possible. The hands should be on the side rather than the back of the ball so the subject cannot flick it with his wrists when he throws. The score is the best of three throws.

4. Soft Ball Throw. The subject stands with his foot on the start line. He throws the ball as far as possible with his preferred hand without moving his feet. The score is the best of three throws.

5. Medicine Ball Put. Subject stands with both feet touching start line

and "puts" medicine ball as far as possible with preferred hand. The other hand may be used to balance the ball. The feet may not move during the throw. Score is the best of three throws.

Static Strength

6. Hand grip. Subject grips dynamometer three times with each hand. The best score for each hand is taken and these are added to give the combined score.

7. Arm Strength. One end of a dynamometer is fastened to the wall. The subject grips the dynamometer with his preferred hand and places the other arm against the wall in a locked position. He then pulls as hard as possible against the dynamometer. The best of three tries is recorded.

8. Trunk Strength. The subject sits on the floor with his back to the wall. Subject's strap is then fastened to the upper body (either under arms or around the shoulders). The other end of the strap is fastened to a dynamometer which is fastened to the wall. The subject places his hands behind his head and sits far enough from the wall so that he is leaning back at about a 30° angle. He then pulls forward as hard as possible. Best of three tries is recorded.

Dynamic Strength - Arms (flexers)

9. Pull-ups (timed). Subject grasps bar with his palms facing toward his body and chins himself as many times as possible in 20 seconds. His chin must reach the bar and his arms must be fully extended during each cycle. The observer will count aloud during the test. If the arms are not extended or the chin does not reach the bar the observer will count 1/2 instead of a full count, so that the subject knows when he is being penalized.

10. Rope Climb. The subject, standing on the knot at the bottom of the rope

grasps the rope with both hands as high as possible and he starts climbing at the start signal. He may not use his feet. Subject climbs as far as he can in 20 seconds. His score is the distance from where his hands touch the rope in the standing position and where they touch the rope at the end of the 20 seconds.

11. Pull Weights. The subject lies face down on a bench with arms down holding a light bar bell under the bench. He pulls the barbell up as many times as possible, extending his arms down fully at the end of each cycle. The score is the number of cycles in 30 seconds. Test 11 should be included in a factor analysis study with the other strength tests to see if Dynamic Strength requires manipulation of the body or if it is general to other activities requiring strength.

Dynamic Strength - Arms (extensors)

12. Dips. The subject grasps the parallel bars at the end. At the start he jumps to an arm rest position which counts as one. He then dips until the arms form a right angle and pushes up to the arm rest position. He does this as many times as possible in 20 seconds. Scoring should be done as in chinning test. Credit should be given for partial cycles. A method for scoring these must be worked out.

13. Push-ups. Subject lies on the floor on his stomach. He does as many push-ups as possible in 30 seconds. Back should be straight at all times. Arms should be fully extended and nose should touch the mat each time. Observer can score as in test 9.

14. Push Weights. Subject lies on back and presses a light barbell, up and down, as many times as possible in 20 seconds. He pushes arms away from the body until arms are extended and returns weight to within one

inch of his chest. Score is the number of times the subject returns the bar to start position. Test 14 should be included in subsequent factor analysis studies for the same reason given for Test 11.

Dynamic Strength - Legs

15. Deep Knee Bends. Subject places hands on hips and does as many deep knee bends as possible in one minute. He should reach a full squat position on each cycle.

16. Push Weights - Feet. Subject lies on back with knees against chest and legs straight up. Metal shoes, with weights inserted, are strapped on. The subject fully extends his legs upward and returns them to the start position as many times as possible in 20 seconds. He is given preliminary trials to permit him to handle the balancing problem. Score is the number of times subject returns to start position.

Dynamic Strength - Trunk

17. Sit-ups (30 seconds). Subject lies on his back with his hands behind his head. The observer holds his legs down at the knees. Subject then does as many sit-ups as possible in 30 seconds.

18. Reverse sit-ups. Subject lies on floor on his stomach with hands behind head. He then raises his torso as far as possible. Observer should note extent of this position before starting test. Subject then resumes prone position before starting test. He raises his torso as many times as possible in 20 seconds. Observer should see that torso is raised as far as possible each time. Observer sits on subject's legs just in front of the knees. Score is the number of times the subject raises himself in 20 seconds.

19. Leg Lifts. Subject lies flat on his back with hands clasped behind

his neck. He raises his legs, keeping them straight, until they are vertical and then returns them to the floor. He repeats this cycle as fast as he can. The score is the number of completed leg lifts in 30 seconds.

Tests 20 through 25 emphasize strength but may involve some endurance. It is likely these tests measure the same factors as their timed counterparts (see above). However, the inclusion of these tests in the same factor analysis studies with shorter, timed strength tests should reveal if a separate component of "endurance" is measured by these tests. Tests 20 through 23 allow the possibility of a Static Endurance factor, where emphasis is on the ability to hold the body in a strained position with the flexor muscles, as distinguished from Tests 24 and 25 which involve repeated flexing.

Dynamic Strength - (Endurance?)

20. Bent Arm Hang. Subject hangs from chinning bar and then, at the start signal pulls himself up until his eyebrows are even with the bar. He holds this position as long as possible. Score is the time this position is held.

21. Hold Half Push-up. Subject lies on stomach, hands on floor under chest in push-up position. At start signal, he pushes himself part way up until elbow forms, roughly, a right angle. He holds this position as long as possible. Score is the time this position is held.

22. Hold Half Sit-up. Subject sits on floor with feet out in front and his hands behind head. On the start signal he leans back about 30° to 40° and holds this position, back straight, as long as possible. Score is the time this position is held.

23. Leg Raiser. The subject lies on back with hands behind head. At signal he raises his legs so that heels are about 12" off floor. He keeps this position as long as possible. Legs must be straight at all times. Score is the time this position is held.

24. Dips (limit). This is done as in test 12, except it is not timed. The score is how many dips the subject is able to do.

25. Pull-ups (limit). This is done as in test 9. The score is how many chins the subject is able to do.

26. Squat Thrusts. From a squat-rest position the subject leans forward and places hands, arms outstretched, on floor in front of him. He returns to the squat-rest position and then stands. This sequence is repeated as rapidly as possible. Score is number completed.

27. Squat Jumps. The subject stands with hands clasped on top of his head and his right foot about 12 inches in front of his left foot. He squats until the right heel touches the right buttock. He then jumps upward until both lower legs are completely extended and the feet have cleared the floor. He then squats until the left heel touches the left buttock. He repeats this cycle as many times as possible. This test is likely to involve the Explosive Strength factor.

28. Step Test. The subject stands in front of a 20" bench. He places one foot on the bench and steps up until both feet are fully on the bench. He steps down one foot at a time. The pace is counted off by the administrator: "Up - 2 - 3 - 4, Up - 2 - 3 - 4," etc. "Up" comes every 2 seconds). Duration in seconds (until exhaustion) is recorded.

Factor analyses of this area might well include Treadmill tests where the subject continues at a given pace until he slows below a critical point. While these tests may not be feasible for routine administration, they would be useful for the experimental factor analysis work to throw light on the nature of the endurance factor.

Run Factor

Tests 26 through 29 are "run" tests and are included in the same study with strength tests to assess the role of the different strength factors in short and longer dashes. Thus, it is possible that short dashes load more highly on Explosive Strength and longer runs load more highly on Dynamic Strength. Inclusion of these runs with strength tests also should demonstrate if a separate "run" factor appears. Such a study would also indicate the generality of a possible "endurance factor".

29. 50 Yard Dash.

30. 10 Yard Dash.

31. 100 Yard Shuttle Run. Two lines are marked off on the floor, 20 yards apart. Subject starts behind one line. He runs to the other line, back again, etc. for five laps, ending up at the far line. Time is scored as for other runs.

32. 600 Yard Run-Walk. From a standing start the subject starts running the 600 yard distance. He may intersperse walking, but the object is to finish as fast as possible. Score is time to finish.

Inclusion of test 32 with the other strength, run, and "endurance" tests should tie down the usefulness of the "endurance" concept as used here.

Tests 33 through 67 may be considered the basis for the second large scale factor analysis study.

Extent Flexibility

33. Kick Height. Subject stands near a graduated scale on the wall and kicks as high as possible with his preferred leg. Observer stands on bench if necessary and notes height of kick. Score is best of three tries.

34. Touch Toes. Subject stands on a bench with his toes even with one edge. He leans over as if to touch his toes, keeping his knees locked.

His score is how far down he can reach. To prevent minus scores, 12 inches above the bench might be taken as zero. If the subject could just touch his toes, then his score would be 12 inches. If he could reach two inches below the edge of the bench, his score would be 14 inches, etc.

35. Twist and Touch. Subject stands with his feet about 12" apart and his toes touching a line at right angles to the wall. This line should also extend vertically up the wall. The subject stands far enough from the wall so that he can just touch it with his doubled up fist with arms outstretched. The subject then twists as far as possible away from the wall (to the right if the wall is on his left) and touches the wall with his hand as far forward of the vertical line as possible. A righthanded subject would normally stand with the wall on his left, turn to the right, and touch the wall as far forward as possible with his right hand. The score is the number of inches in the subject's reach forward of the vertical line. The observer should be sure that the subject's feet remain firmly planted in position during the test.

Dynamic Flexibility

36. Twist Flexibility. A belt or strap is tied about the subject's body and arms just above the elbows so that the arms cannot be moved except from the elbows. The subject then stands with his feet slightly apart and his forearms held straight out in front of him. Uprights are then placed on either side of him so that the two uprights and the center of the subject's body are in a line. First, the upright is placed far enough from the subject so that he can just touch it with both hands by twisting his body to one side or the other, holding his arms out at right angles to his body. Two marks are made on each upright at the level of the subject's

elbows and 18" below this. At the start of the test the subject stands upright, facing straight forward, with his forearms held out in front of him. At the start signal he twists his body and touches the upper mark on the right stanchion with both hands. He then stoops and touches the lower mark with both hands, twists to touch the lower mark on the left stanchion, rises to touch the upper mark on the left stanchion, touches the upper mark on the right stanchion, etc. He makes as many cycles as possible in 30 seconds. His score is the number of cycles completed. Partial scores are given for partially completed cycles. An alternate method of scoring is for the observer to time 20 cycles in tenths of seconds. A cycle is completed when the subject touches the upper mark on the left stanchion. In this method, the observer should count the cycles aloud as they are completed. Observer should be sure that the subject touches all marks with both hands.

37. Stoop-twist. Subject stands with his heels 18" from the wall facing away from it. There is a 6" circle on the wall which should be even with the subject's shoulders and directly behind him. The subject stoops and touches the floor between his feet, rises and twists to touch the circle on the floor again, etc. His score is the number of cycles he can complete in 30 seconds.

38. Shuffle. Any line on the gym floor may be used for this test. There should be two marks at right angles to the line and 20' apart. The subject stands on one of these marks with his hands on his hips. At the start signal he moves sideways down the line by moving first both toes, then both heels, etc. keeping both feet together at all times. He shuffles to the other mark and back, a total distance of 40'. His score is the time

required in tenths of seconds. If the subject separates his feet he must take the test from the beginning again.

Speed of Limb Movement - Arms

39. Two Plate Tapping. Two 6' disks are used as above. These are placed on a table about 12" apart. Subject taps them in succession as rapidly as possible for 30 seconds. Score is the number of taps on one plate.

40. Arm Circling. The subject, standing, leans over a waste basket (13-14" in diameter) and swings his preferred arm so that his hand goes completely around the circumference of the basket. His score is the number of complete revolution in 20 seconds.

41. Block Transfer. This requires two trays about 12" square with sides about 1/2 inch tall. Each tray contains 20, 1" square blocks. The subject, using his preferred hand, transfers all the blocks from one tray to the other as rapidly as possible, taking only one block at a time. He then transfers them back, etc. The blocks should be transferred four times so that they end up in the original tray. Score is the number of seconds required for the task.

Speed of Limb Movememt - Legs

42. One Foot Tapping. The subject sits on a chair facing with his foot resting on the right side of a flat 18" board. The board has a 6" perpendicular partition in its center. He is required to lift his foot over the partition, laterally, and tap the other side of the board. He completes as many back and forth tapping movements as possible in 20 seconds.

43. Two foot Tapping. The subject stands facing the wall, lifts his right foot, and taps the kick board twice before returning it to the ground. The kick board is 12" square and 18" off the ground. He does the same with his left foot and repeats the cycle as many times as possible in 15 seconds.

44. Leg circling. The subject stands so that he can swing his leg around the circumference of a waste basket. He holds on to two chairs for support. His score is the number of revolutions in 15 seconds.

Speed of Change of Direction

45. Dodge Run. Any obstacles can be used though upright stanchions would probably be best. The stanchions should be set in a straight line at 15', 30', 45', and 60' from the base line. The subject starts at the base line at a point in line with the row of stanchions. He runs to the right of the first stanchion, to the left of the second, to the right of the third, around the fourth, left of the third, right of the second, left of the first and back to the base line. His score is time in tenths of a second. He may not touch any of the stanchions.

46. Potato Race. This test requires two parallel lines on the floor, 15' apart. The subject starts behind one line, runs across the other line (both feet must cross the line) runs back across first line, etc. Score is time for five round trips, i.e., 150'.

47. Figure Duck. Two stanchions are set up, 10' apart. A light rod is fastened to these at the height of the subject's shoulders. A high-jumping apparatus may be used if available. Subject starts at the right side of one of the uprights. He ducks under the rod, goes around the far pole, back around the first, etc., in figure eight fashion, ducking the upright each time. His score is the time required for ten figure cycles.

48. Zig-zag. This test requires two parallel lines 20' apart and at right angles to a base line. Place six uprights on these lines, two at the intersections with the base line, two 20' from the base line, and two 40' from the base line. The uprights on the left line will be called 1, 2,

and 3, starting at the base line. Those on the right will be 4, 5, 6 starting from the base line. Subject starts at pole 1. He runs to pole 4, touches it, runs to pole 2, touching it, etc. The subject does not run around the poles, but just touches them with either hand. He starts at pole 1, then touches 4, 2, 5, 3, 6, 2, 5, 1, 4. His score is the time in seconds.

The Shuttle Run test (test 28) previously described should be included here. The inclusion of straight run tests here should indicate if "speed of change of direction" is a distinct factor.

Coordination

49. Throw and Catch. Subject stands behind a line 20' from the wall and bounces a tennis ball against the wall. His score is how long, in tenths of a second, that it takes him to bounce the ball against the wall 20 times. If the ball touches the floor at any time the test must be started over.

50. Bar Vault. The subject vaults over a bar using only his hands. The bar should be raised 2" at a time and when the subject fails three times in a row the last position of the bar is taken as his score.

51. Dribble. Subject dribbles a basketball back and forth between two lines 20' apart on the floor. The ball must bounce at least once on the far side of each line. He dribbles over and back for a total of 40'. His score is the time required in tenths of a second. If he loses the ball, he may start over again.

52. Jump and Turn. There should be a circle on the floor, about 18" in diameter. At least eight equally spaced line should radiate from the center of the circle. The subject stands in the middle of the circle with his feet pointing to one of the lines. He then jumps and turns around as

far as possible, landing on both feet in the same place. His score is the number of segments of the circle between his original position and the final position. The best of three tries is used as his test score.

53. Grass Drill. Two chairs are placed 7' apart. The subject gets down on all fours, hands and feet, beside one of the chairs. On signal "GO", the subject, on all fours, travels around the first chair, goes between the chairs, around the second chair, and back between the chairs to his starting point, thus completing the figure 8. This completes one cycle. The subject's score is the length of time required to complete four cycles.

54. Cable Jump. The subject is given a 16" length of 1/8" diameter flexible wire cable. Handles 4" in length are attached to each end. He holds the cable by the handles, and jumps over it, maintaining balance when landing. The score is the number of correctly performed jumps out of five attempts.

Static Balance

55. One Foot Lengthwise Balance - Eyes Open. The subject balances on a rail (1 1/2" high, 3/4" wide and 24" long) using the preferred foot with the long axis of the rail parallel to the long axis of the foot. The subject keeps hands on his hips and he says "Go" when he feels he is balanced. Score is the time until he touches the floor or removes either hand from his hips.

56. One Foot Lengthwise Balance - Eyes Closed. Same as test 55 except eyes kept closed.

57. One Foot Crosswise Balance - Eyes Open. This is the same as test 55 except the subject balances on the ball of the foot with the long axis of the rail perpendicular to the long axis of the foot.

58. One Foot Crosswise Balance - Eyes Closed. Same as test 57 with eyes closed.

59. Two Foot Lengthwise Balance - Eyes Open. This is the same as test 55 except that two feet are used on the balance rail and must maintain contact with it throughout.

60. Two Foot Lengthwise Balance - Eyes Closed. Same as test 59 with eyes closed.

61. Two Foot Crosswise Balance - Eyes Open. This is the same as test 59 except feet are held crosswise.

62. Two Foot Crosswise Balance - Eyes Closed. Same as test 61 - with eyes closed.

Dynamic Balance

63. Circular Rail Walking. A hexagonal rail, made up of 6 boards 3/4" wide, 3 1/2" deep, and 24" long is used. The subject starts at the beginning of a segment, hands on hips, and walks backward around the hexagon as long as possible, putting one foot in back of the other. The subject cannot put more than one foot on any segment and no foot may overlap segments. A subject's score is the number of segments traversed before the subject falls or removes his hands from his hips. The test score is the better of two tries.

64. Board Balance. A teeter board made up of a board 24" x 12" x 1" supported by a 12" long, 2" x 4". The bottom of the 2" x 4" has the edges planed off at an angle so that the width of surface in contact with the floor was only one inch. The subject balances himself on the teeter board by placing one hand on the tester's shoulder for support. When the subject feels he has his balance and wants to start, he removes his hand from the

tester's shoulder. This is the signal for the tester to start the stop watch. The subject's score is the length of time he maintains his balance. His balance is lost when he falls off the board or when either end of the teeter board touches the floor.

65. Hop into Circles. Eight 12" circles, equally spaced, are drawn on the floor in a large circle. The subject stands in one circle on the ball of his preferred foot, hands on hips, eyes open. He then hops around the big circle, landing each time in the next one of the small circles. Trial ends when the other foot touches, the floor, hands leave the hips, or the subject looses his balance. Subject may not stand in any circle more than five seconds. Score is the number of circles touched before the end of his trial. Test score is the best of three trials.

Balancing Objects

66. Ball Balance. The subject balances a volley ball on the back of his closed fist, using his preferred hand, holding his hand at shoulder height. The subject is not allowed to move his feet. The subject determines starting signal. When he has balanced the ball and wants to start, he says, "GO". Time ends when the subject touches the ball with any other part of his body or the ball falls to the floor. The subject's score is the length of time he keeps the ball balanced. Test score is the best of three trials.

67. Stick Balance. The subject balances a yardstick on the index finger of his preferred hand for as long as possible. Otherwise, this is the same as for test 66.

The inclusion of these balance tests in the same study (tests 55-67) should allow answers to the following questions: 1) do tests with eyes open appear on the same factor as tests with eyes closed or are separate balance factors involved, 2) do tests requiring balancing during performance involve a separate factor from more static equilibrium maintenance tests, 3) is a balance factor general to tasks involving the balancing of objects by the body as well as those involving balancing of the body?

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