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ABSTRACT

Twenty-one variables believed to be important indicators of health related physical fitness were measured on male and female college students between 1991 and 1993 (n=433). Exploratory and confirmatory factor analytic techniques were used in an attempt to derive important components of physical fitness. The exploratory factor analysis identified five important factors of collegiate physical fitness: (1) strength and endurance; (2) body composition; (3) heart rate; (4) blood pressure; and (5) flexibility. For the confirmatory factor analysis, an a priori model similar to that developed by Marsh (1992) and one similar to the American College of Sports Medicine (ACSM) were tested in which body composition, body girth, muscular strength and endurance, cardiorespiratory fitness, flexibility, blood pressure, and cardiac functioning were hypothesized as important fitness parameters. Results of the confirmatory factor analysis indicate that neither the ACSM nor Marsh's model provided good fits for these students. Reliability estimates were high but poor validity and goodness of fit indices were found. This indicates that common fitness measurement techniques may be inadequate when assessing college students' fitness levels. (Contains 11 references and 3 tables.) (SLD)

EXPLORATORY VERSUS CONFIRMATORY FACTOR ANALYSIS

OF COLLEGIATE PHYSICAL FITNESS

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ABSTRACT

Twenty-one variables believed to be important indicators of health related physical fitness were measured on male and female college students between 1991 and 1993 (n=443). Exploratory and confirmatory factor analytic techniques were used in an attempt to derive important components of physical fitness. Recent definitions stress cardiorespiratory endurance, muscular strength and endurance, body composition, and flexibility as key ingredients of health-related physical fitness (Baumgartner & Jackson, 1987; American College of Sports Medicine, 1991). In this study, the exploratory factor analysis identified five important factors of collegiate physical fitness: strength and endurance, body composition, heart rate, blood pressure, and flexibility. For the confirmatory factor analysis, an a priori model similar to that developed by Marsh (1992) and one similar to the American College of Sports Medicine (ACSM) were tested in which body composition, body girth, muscular strength and endurance, cardiorespiratory fitness, flexibility, blood pressure, and cardiac functioning were hypothesized as important fitness paramaters. Results of the confirmatory factor analysis indicated that neither the ASCM's nor Marsh's model of physical fitness provided good fits for these college students. Reliability estimates were high but poor validity and goodness of fit indices were found. This indicates that common fitness measurement techniques may be inadequate when assessing college students fitness levels.

Key words. exploratory factor analysis, confirmatory factor analysis, physical fitness, reliability, validity

Over the last decade, a growing research interest in defining and identifying key ingredients of physical fitness has occurred. This interest has stemmed from the American populations desire to maintain physical fitness and recent evidence that American youth are less physically fit than previous generations (e.g. Pierce, 1992). The outcome of this research has been numerous definitions of physical fitness that are not empirically derived or tested. Casperson et. al. (1985) defined physical fitness as "a set of attributes that people have or achieve that relates to the ability to perform physical activity." This definition is somewhat dated in that in recent years, the concept has diverted more from athletic domains to health related concerns. Health related physical fitness was characterized by Pate (1988) as "an ability to perform daily activities with vigor, and the demonstration of traits and capacities that are associated with low risk of premature development of hypokinetic diseases."

Presently, the most popular theory of health-related physical fitness is the position held by the American College of Sports Medicine (ACSM). The ACSM (1991) proposed five indicators of physical fitness: muscular strength, muscular endurance, body composition, cardiorespiratory endurance, and flexibility. The ACSM adopted criteria from the American Alliance for Health, Physical Education, Recreation, and Dance (AAHPERD) Health Related Physical Fitness Test and recommendations by Baumgartner and Jackson (1987). The validity and reliability of these components and their indicators are well documented (AAHPERD, 1984). However, neither organization described how these separate components were derived or tested. Since it is widely believed that physical fitness contains many dimensions and is determined by a wide range of functional capacities and abilities of the individual (Safrit, 1981), the dimensions that reflect those individual capacities need to be empirically derived and tested. The purpose of this study was to determine through exploratory and confirmatory factor analysis the components of physical fitness that underly its definition.

Factor analytic techniques to derive physical fitness components have received very little attention in the published literature. Currently, there are only two published studies that identified its components through empirical derivations. Fleishman (1964) pioneered the use of factor analysis in physical education in order to identify fitness components that could be used in a comprehensive fitness battery. Fleishman's subjects were United States Navy recruits who were tested on factors of strength, speed, flexibility, balance, and coordination. Strength was subdivided into dynamic strength, static strength, and explosive strength. Dynamic strength was

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measured by such skills as pullups pushups, bent arm hang, rope climb, dips, and squat thrusts Static strength was measured through the use of dynometers as subjects were tested on the ability to apply force to lift or push weights. Explosive strength was measured by jumping and sprinting activities along with the softball throw.

Based on the exploratory factor analysis of all measurements, Fleishman identified six factors: explosive strength, limb speed, balance with visual cues, gross body equilibrium, dynamic flexibility, and extent flexibility. Despite the extraction of six factors, these separate factors of fitness only explained the variance of the measured variables. Where Fleishman's study may have been limited was in the omission of cardiovascular endurance assessments and the lack of validity and reliability estimates that are provided through confirmatory factor analytic tests. Fleishman also did not discuss the correlations among the extracted factors. The inclusion of endurance measurements may have provided different results in the Fleishman study. Confirmatory tests of the Fleishman model may also influence his description of fitness.

The most recent factor analytic investigation of physical fitness was reported by Marsh (1992). Marsh incorporated modern advances in confirmatory factor analysis to test an a priori structural equation model of physical fitness from a 1985 survey based on twenty-five fitness measurements of nearly three thousand Australian boys and girls aged nine, twelve, and fifteen years. Marsh hypothesized nine a priori fitness factors: cardiovascular endurance, explosive strength, dynamic strength, static strength, flexibility, blood pressure, lung function, body girth, and skinfolds. Cardiovascular endurance indicators were maximal oxygen uptake based on a subset of the sample, 1.6k run time, and physical work capacity (Kmg/kg x min) as measured on a Monark bicycle using 3 minute increments of increasing difficulty. Explosive strength indicators were 50 meter dash and standing long jump. Dynamic strength included thirty second situps and number of pushups done at a cadence of 20/minute with 100 being the maximum. Static strength indicators were grip, shoulder push and pull, and leg strength. Flexibility was measured by a sit and reach test. Lung function was determined by one second forced expiratory volume and forced vital capacity. Body girth indicators were mid-arm, waist, and hip girth. Skinfolds were taken at five different anatomical sites: biceps, triceps, subscapular, suprailiac, and midabdomen.

A confirmatory factor analysis of Marsh's data resulted in a good fit between the measured data and factor structure when explosive and dynamic strength were combined into one factor. With the exception of physical work capacity and pushups, the variables highly loaded on the a priori structural model. Marsh further observed that the model was invariant across the three age groups and across gender. Thus, the structural model was useful in explaining fitness for all groups

Both Fleishman and Marsh provided solid evidence that physical fitness is a multidimensional construct which cannot be assessed by a single indicator. However, they disagreed on the application of their results. Fleishman believed that standard scores could be generated from the factors in order to compare ones fitness across age levels and ability. Marsh strongly argued against providing a composite score of physical fitness based on the factor strucure. According to Marsh, "considerable information in the specific factors would be lost in the formation of a single total score." He argued that multiple sets of scores should be collected over time for the same individual such that indications of achieving ones personal best could be determined rather than comparing one's total fitness score to the rest of the population.

For the present study, two models of fitness were tested. In the first model, seven a priori factors, five based on ACSM's guidelines and two additional factors, were analyzed through both exploratory and confirmatory methods in an attempt to define physical fitness. The second a priori model of physical fitness underwent confirmatory testing and involved only the five components of physical fitness taken from the ACSM. The components of fitness were assessed through indicators consistent with ACSM definitions. Cardiorespiratory endurance was defined as the ability to perform large muscle, dynamic, moderate-to-high intensity exercise for prolonged periods. Body composition referred to lean body tissue or percent body fat. Muscular strength was defined as the maximal force that could be generated by a specific muscle or muscle group. Muscular endurance was the ability of a muscle group to execute repeated contractions over a period of sufficient time duration to cause muscular fatigue. Flexibility was the maximum ability to move a joint through a range of motion. The two final a priori factors were heart rate and blood pressure.

METHOD

The sample consisted of 434 college undergraduates enrolled in Exercise and Health classes at the University of Toledo between 1991 and 1993. Participants ranged in age from 18 to 50 with the mean age of 21.6 with a standard deviation of 4.9. Two hundred and thirty-five of the subjects were female. Subjects were measured over three consecutive class days on a variety of variables believed to be important predictors of physical fitness. A total of twenty-one variables was measured on all subjects.

Measurements of body composition consisted of chest/tricep (CHT), abdomen (ABS), and thigh (THI) fat, total body fat percentage (PBF), and waist circumference (WAI). Skinfold measurements were expressed in millimeters as determined by a Slimguide skinfold caliper. For the variable CHT, males were measured at the right pectoral and females at the right tricep. Muscular endurance indicators were the number of bent knee situps done in sixty seconds (SSU) using the alternating contralateral elbow to knee style and the number of full range of motion standard pushups (males) or modified pushups (females) done in sixty seconds (SPU). Cardiorespiratory endurance measurements were one mile walk time (OMW), one mile run time (OMR), and twelve minute run distance (TMR) (ACSM, 1991). All estimators of cardiorespiratory endurance were completed on an indoor track with nine and a quarter laps equalling a mile. The measurements of endurance were done on separate days with at least two days of rest between measurements. Flexibility was assessed by a standard sit and reach test (TRF) and was recorded in inches. Muscular strength indicators were maximum bench press (BP), maximum leg extension (LEG), and maximum arm curl (BAC). BP and BAC were completed on universal weight machines and LEG was measured using only one leg on universal or nautilus equipment. Systolic (SYS) and diastolic (DIA) blood pressure readings expressed in mg served as measurements of blood pressure. Exercise heart rate (EHR), two minute recovery heart rate (TMR), and resting heart rate (RHR) served as indicators of heart rate. Blood pressure readings and RHR were measured following no less than forty-five minutes of rest. EHR and TMR were self-reported after completing the twelve minute run distance The final measured variable was height (HGT) which was recorded in inches.

RESULTS

Exploratory Factor Analysis

To arrive at the best solution, an oblique rotation of the data was conducted. An orthogonal rotation only converged when numbers on the principal diagonal were significantly altered from one. The oblique rotation converged in twenty-eight iterations. Table I lists the variables that loaded highly in the structure matrix and their correlation with that factor. Five significant factors were extracted based on the Kaiser rule.

Insert Table I

Based on the variable loadings, factor 1 was identified as 'strength and endurance', factor 2, 'body composition', factor 3, 'heart rate', factor 4, 'blood pressure', and factor 5, 'flexibility'. Strength and Endurance accounted for 28.6% of the variance followed by body composition, 19.1%, cardiac function, 8.5%, flexibility, 5.6%, and blood pressure, 5.3%. Despite the extraction of five separate fitness components, the factors were not orthogonal. Factors 2 and 5 and factors 4 and 5 were somewhat related, -.27 and .26, respectively.

Confirmatory Factor Analysis

To determine whether the specified a priori model better fit the data than achieved through a posteori exploratory factor analysis, a confirmatory factor analysis using LISREL 7 software was computed (Joreskog & Sorbom, 1988). The original a priori model specified cardiorespiratory endurance, muscular strength and endurance, body composition, blood pressure, heart rate, and flexibility as the latent variables. The variables that were hypothesized to load onto these factors are listed in Figure 1.

The first a priori model provided a poor fit with the data, X^2 (114)=898.41, p<.001. Construct validity, the clustering of observed variables around their latent constructs (Mueller, 1993), was poor. Small factor loadings were observed when compared to their standard errors. However, reliability estimates, squared multiple correlations of the observed variables (Mueller, 1993), were moderately high. Total coefficient of determination equalled .999. Table II gives the standardized loadings in lambda X. Table III provides the reliability estimates of the seven factor model.

Insert Tables II and III here

The second a priori model tested was based on the ACSM's guidelines. Cardiorespiratory endurance, muscular strength and endurance, body composition, and flexibility were hypothesized as the key components of fitness. For this model, a poor goodness of fit index was also found, χ^2 [illegible] 87, $p < .001$. As with the previous model, construct validity was weak and reliability estimates were moderately high. Total coefficient of determination equalled .999. Standardized factor loadings and reliability estimates were similar to the values expressed in Tables II and III.

DISCUSSION

The results of the present investigation yielded two important general findings. The first was that modern techniques in factor analysis and structural equation modeling need to be incorporated into exploratory research methods. Acceptance of structural models in all realms of science is inadequate unless validity and reliability estimates of significance along with "goodness of fit" tests are calculated. Making decisions solely on exploratory research techniques may lead to inaccurate and misleading interpretations. In the present study, the exploratory analysis yielded similar outcomes to other previous research in physical fitness but these results were not supported by the confirmatory testing. Exploratory factor analysis yielded five important elements of physical fitness that were later rejected through confirmatory factor analysis.

A second important finding was the confirmation of physical fitness as a multidimensional construct. Clearly, and consistent with previous literature, physical fitness needs to be assessed by a variety of techniques that measure the functional abilities of the individual. According to this study, those functional abilities may relate to ones muscular strength and endurance, cardiorespiratory endurance, body composition, flexibility, cardiac functioning, and blood pressure. However, according to this study, using solely these criteria for assessing fitness is inadequate. Attempts at accepting these components into a model of physical fitness failed. Thus, for a college population, the definition of health-related physical fitness may be moderately different than proposed by the ACSM and AAHPERD organizations. This study used their recommendations of physical fitness components and indicators to arrive at solutions that did not support their definition.

This study is inconsistent with attempts to define separate components of physical fitness in order to compute a total fitness score. In agreement with Marsh (1993), a total score would be inaccurate not only because arbitrary weights would be assigned and critical information would be lost, but also because the components are not orthogonal. Repeated attempts to arrive at a model that identified separate components of fitness failed. The exploratory analysis indicated that factors cardiorespiratory endurance and muscular strength and endurance were highly related. Similarly, blood pressure and body composition were somewhat related. Therefore, without taking into account the nature of the relationships between the factors and even if the confirmatory analysis found an admissable solution, a fitness score based on separate components would be inadequate even with assigned weights.

It could be argued that the removal of variables from the model with low reliability scores and poor factor loadings would lead to an admissable solution. However, in this case, it would lead to lower than three variables loading onto a factor and weaken the construct validity of the model (Marsh, 1992). Since a limited number of variables were used to estimate their underlying construct, the removal of variables from the model was not conducted. Repeated attempts to define an acceptable model while maintaining construct validity failed. The results of the confirmatory analysis indicate that for this data and this sample, an acceptable model of physical fitness may not exist.

Although discrepant with Marsh's findings, clear and distinct categories of physical fitness could not be derived from this sample. Marsh derived eight latent factors that validly comprised physical fitness but his discussion on the reliability of the indicators was limited. When an a priori model similar to Marsh was analyzed, reliability scores were moderately high but validity estimates were weak. Similar results were also observed for the ACSM model of physical fitness.

Where this study differs from the Marsh study was in the tests of gender and age groups. This study did not attempt to create models of fitness for each age group or gender. Perhaps if the model testing considered these variables, could an acceptable model of fitness be found. An acceptable model may also have been found if variables that included lung function, dynamic and extent flexibility, motor ability, and differing strength measurements were incorporated into the study. A factor cannot be derived that was not measured. This study largely relied upon recommendations by the AAHPERD and ACSM organizations which did not include these variables.

When measuring health related physical fitness, physical educators should not treat its components as separate elements but rather, as a multidimensional construct that contains highly dependent elements. Most noteworthy was a high dependence of endurance, strength, and body composition measurements and a positive relationship between the factor body composition and girth and the factor blood pressure (r=.59). Attempts at separating the three factors to define fitness levels are extremely cautioned.

This information can be useful in assessing physical fitness of collegiate subjects and can assist physical educators in utilizing appropriate batteries and tests of fitness. However, until the relationships between the components are incorporated into an equation that specifies each fitness indicator and until further derivation studies of fitness are conducted that investigate differences in age, gender, race, etc., repeated performance comparisons within an individual may be the most important marker of physical fitness (Marsh, 1992).

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Table 1

Significant loadings of each variable on the factors in the exploratory structure matrix

Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
TM[illegible](.838)	PBF(.630)	TMR(.886)	TRF(.756)	SYS(.882)
SSU(.772)	THI(.514)	EHR(.845)	HGT(-.560)	DIA(.857)
OMR(-.764)	ABS(.854)	RHR(.469)		
SPU(.727)	WAI(.802)			
PBF(.718)	CHT(.691)			
BP(.715)				
BAC(.685)				
THI(- .675)				
LEG(.545)				
OMW(- .529)				
HGT(.464)				

Table II

Standardized maximum likelihood estimates of the freed parameters of the seven factor model

Variables	Cardio End.	Musc. End.	Mus. Str.	Body Comp.	Heart Rate	Flex.	Blood Press.
TMD	.875						
OMR	-.817						
OMW	-.562						
SSU		.768					
SPU		.794					
BP			.876				
BAC			.851				
LEG			.524				
PBF				.263			
CHT				.756			
ABS				.741			
WAI				.919			
THI				.763			
EHR					.628		
RHR					.241		
TMR					1.04		
TRF						.707	
SYS							.793
DIA							.782

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Table III

Reliability estimates of each variable in measuring their underlying construct in the seven factor model

Reliability Variable	Coefficient	Reliability Variable	Coefficient
TMD	.782	OMR	.763
OMW	.584	SSU	.711
SPU	.685	BP	.767
BAC	.750	LEG	.542
PBF	.711	CHT	.748
ABS	.510	WAI	.278
THI	.775	EHR	.734
RHR	.221	TMR	.717
SYS	.702	DIA	.654