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Correlates to Performance on Field Tests of Muscular Strength

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Field tests of upper body muscular strength and endurance (UBMSE) are often administered to children, but little is known about the determinants of performance on these tests. Therefore the purpose of this investigation was to examine potential determinants of performance on several common field tests of UBMSE including pull-ups, flexed-arm hang, push-ups, and two types of modified pull-ups. Subjects were 56 girls and 38 boys, ages 9 to 11 years. Potential determinants assessed were age, height, weight, gender, % fat, physical activity, and laboratory measures of muscular strength and endurance. Multiple regression analysis revealed that the laboratory measures of UBMSE failed to account for significant fractions of variance in performance on four of the five tests. However, % fat was significantly associated with performance on four of five tests. These results indicate that factors other than muscular strength and endurance account for most of the variance in performance, and that % fat appears to be a particularly important determinant of performance.

Physical fitness batteries have been widely used in school based physical education programs for many years (1, 3, 8, 13). Typically these test batteries have included several test items, each of which has been selected to measure a specified component of physical fitness. Most of the test batteries used in physical education programs in the United States have included a test item designed to measure a component of physical fitness that is described as upper body muscular strength and endurance (UBMSE). At present, while there is apparent agreement that UBMSE should be measured in field fitness tests (8), there is no consensus on the most appropriate method for measuring this fitness component. Among the test items that have been widely used are the pull-up (1), flexed-arm hang (1), push-up (3), and modified pull-up tests (11, 17).

Although field tests of UBMSE are often administered to children and youth, little is known about the determinants of performance on these tests in youngsters. It seems clear that such tests are included in fitness test batteries because performance on them appears to depend on the strength/endurance of the muscle groups of the upper arm girdle. That is, the tests have "face validity." However, work from our laboratory and others has revealed that the correlation

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coefficients between criterion measures of UBMSE and performance on many of these tests (e.g., pull-up and flexed-arm hang) are in the low to moderate range (12, 13). This implies that factors other than strength and endurance must account for much of the variance in performance on field tests such as the pull-up. The relative importance of factors such as gender, body weight, and body composition have not been described previously in children. As such, the purpose of this study was to examine the potential determinants of performance on several common field tests of upper body muscular strength and endurance.

Methods

Subjects were 56 girls and 38 boys, ages 9 to 11, who were 4th and 5th grade students in Lexington County, South Carolina. Descriptive data are presented in Table 1.

The subjects completed several common field tests of upper body muscular strength and endurance. Most subjects completed each test on two occasions (test-retest) separated by not more than 10 days. The tests administered were pull-ups (PU), flexed-arm hang (FAH), push-ups (Push), and two types of modified pull-ups. These tests were administered at the schools by trained investigators. One investigator administered the same test throughout the study. Pull-up and FAH tests were administered in the standard fashion as described by AAHPERD (1). Push-ups were administered according to the procedures described by the Chrysler Fund–Amateur Athletic Union (3).

One form of modified pull-ups (Vermont modified pull-up, VMPU) was administered using a simple apparatus as employed in Phase II of the National Children and Youth Fitness Study (17). Another form of modified pull-up (New York modified pull-up, NYMPU) was taken from an early version of the New York State Fitness Test battery (11). Performance of these two tests requires an adjustable horizontal bar, the height of which can be adjusted so that the subject's feet are in contact with the floor. In a supine position the subject maintains the hips and knees fully extended as pull-ups are performed.

Tests were explained and proper form was demonstrated to each child prior to each performance. Investigators carefully followed the prescribed guidelines in administering each test. Tests were administered in random order. Subjects were allowed a minimum of 10 minutes rest between tests, and no more than two tests were given in a day. Tests were administered with small groups of children present in isolated areas of the gymnasiums. Verbal encouragement was given in a consistent manner by the investigator and children.

In addition, each subject completed several laboratory measures of UBMSE at the University of South Carolina's Human Performance Laboratory. These tests involved isotonic muscle contractions on a set-resistance Universal Gym designed to determine one-repetition maximum (1-RM) scores. Due to the large weight increments imposed by the Universal Gym, 1-kg strap weights were added to allow for higher resolution in 1-RM and endurance measures. Bench press, forearm curl, and latissimus dorsi pull-down 1-RM scores were determined and the scores were converted to standard scores and summed to provide a composite strength score (Sum 1-RM). Furthermore, each subject performed upper body muscular endurance tests for the bench press, latissimus dorsi pull-down, and forearm curl movements. The endurance tests used 50% of individual 1-RM and were scored as the highest number of repetitions that could be performed for each test (2). Like the strength scores, endurance scores were standardized and summed to provide a composite endurance score (SumEnd) for use in subsequent analyses.

Several other measures were also obtained during the visit to the laboratory. Height and weight were recorded, and percent body fat was estimated from the sum of triceps and subscapular skinfolds as described by Lohman (10). Estimates of physical activity and participation in structured community activities were obtained from a modified version of a questionnaire used in the National Children and Youth Fitness Study I (16). Physical activity was assessed as the self-reported number of physical activities (chosen from a list of 86 activities) performed in the year prior to the study. Organized recreational activity was assessed as the number of organizations (e.g., church, recreation centers) through which the child had participated in physical activity. This questionnaire has not been validated; however physical activity as assessed by this instrument has been shown to correlate significantly with physical fitness (16).

Mean and standard error were computed for all variables, and Pearson zero-order correlation coefficients were computed to examine most associations among independent variables and between the dependent and independent variables. Point biserial correlation was used to examine associations between gender and the other variables. Due to the highly skewed nature of the field test data, these scores were log transformed to meet the assumption of normality in the Pearson analysis. Several independent variables were examined as potential determinants of field test performance. These included age (to nearest month), gender, height, weight, percent body fat, number of physical activities, organized recreational activities, Sum 1-RM, and SumEnd.

Associations among the independent variables were determined by computing zero-order correlation coefficients. The independent associations between the selected predictor variables and each field test performance were assessed using multiple regression analysis in which all the independent variables were forced into the regression model. Also, a forward stepwise multiple regression was performed in order to generate models that explained the greatest amount of variance in test scores and to quantify the amount of variation explained by individual variables. In this procedure the computer added variables (from a list of all independent variables) one by one to the model if the probability for entry was $p<.05$. After addition, the procedure analyzed the new model with all variables included to that point and deleted any that did not produce a significant F statistic at the chosen level $p<.05$. All statistical analyses were performed using programs available in the Statistical Analysis System (18).

Results

Group means and standard errors for the dependent and independent variables observed in this study are presented in Table 1. Data are presented separately for boys and girls as well as for the entire group. Mean age was 10.0 $\pm$0.07 years for the 94 children. Mean height and weight for this group were typical of 10-year-olds in the U.S. (14).

Table 2 presents the zero-order correlation coefficients computed among the independent variables. Results reveal that, while many variable pairs were significantly correlated ($p<.05$), in general the fractions of variance shared were

Table 1

Means for Independent and Dependent Variables ($M \pm SEM$)

	All subjects ($n = 94$) Mean	*SEM*	Boys ($n = 38$) Mean	*SEM*	Girls ($n = 56$) Mean	*SEM*
Age (yrs)	10.0	0.07	10.0	0.12	9.9	0.08
Height (cm)	142.4	0.76	142.4	1.19	142.4	1.0
Weight (kg)	37.0	0.81	37.8	1.24	36.4	1.08
Sum of triceps & subscap. skinfolds (mm)	25.1	1.12	24.1	1.82	25.7	1.43
% Body fat	22.7	0.69	20.7	1.12	24.0	0.83
Physical activity (no. activities)	23.5	1.34	22.9	2.33	23.8	1.64
Organized recreation (no. settings)	2.7	0.19	2.8	0.34	2.6	0.23
Bench press 1-RM (kg)	20.9	0.49	23.6	0.48	19.0	0.44
Lat pull-down 1-RM (kg)	26.5	0.53	29.4	0.81	24.5	0.55
Biceps curl 1-RM (kg)	8.9	0.25	10.1	0.37	8.1	0.28
Bench press endurance (no. reps @ 50% 1-RM)	18.3	0.33	19.9	1.23	17.3	0.86
Lat pull-down endurance (no. reps @ 50% 1-RM)	55.2	1.68	52.6	6.3	57.0	4.51
Biceps curl endurance (no. reps @ 50% 1-RM)	12.1	0.28	13.9	0.89	10.8	0.83
Pull-ups (no. reps)	0.5	0.09	0.7	0.19	0.3	0.09
Flexed-arm hang (sec)	7.5	0.68	9.1	1.28	6.4	0.70
Vermont modified pull-ups (no. reps)	6.4	0.32	7.6	0.54	5.5	0.35
Push-ups (no. reps)	2.5	0.29	4.3	0.57	1.2	0.19
New York modified pull-ups (no. reps)	4.4	0.42	5.5	0.72	3.7	0.49

Table 2

Correlations Among Independent Variables

	Age	Gender	Ht	Wt	% Body fat	Phys. activ.	Organ. rec.	Sum 1-RM
Age	X							
Gender	–.10	X						
Ht	.46*	.00	X					
Wt	.30*	–.09	.66*	X				
% Body fat	.00	.24*	.25*	.71*	X			
Physical activity	.25*	.03	.13	.00	–.08	X		
Organized recreation	.13	–.07	.10	.11	.06	.45*	X	
Sum 1 RM	.36*	–.52*	.42*	.59*	.13	.00	.10	X
Sum End	.08	–.24*	.16	.21	.11	.23*	.28*	.32*

*$p \leq .05$.

quite low (R^2<25%). However, as expected, relatively high correlations (r>.65) were observed between height and weight and between weight and percent body fat. The zero-order correlation coefficients between the dependent variables (log transformed) and independent variables are presented in Table 3. In general, height, weight, percent body fat, and female gender were found to be significantly (p<.05) and negatively correlated with performance on the field tests. In these univariate analyses, age, the physical activity measures, and the laboratory measures of muscular strength and endurance were not significantly associated with test performance.

Five separate multiple regression analyses were performed using the same set of independent variables, but with each of the five field tests entered as the dependent variable. Results of these analyses are summarized in Table 4. This table includes standardized beta coefficients that indicate the direction and relative magnitude of each association. Results for the pull-up test revealed that percent body fat and height entered the multiple regression model and that both were negatively associated with test performance, such that the taller and fatter children scored lower on this test. Results with the NYMPU test indicated that none of the independent variables were important in predicting scores on this test. Percent body fat was negatively associated with scores on the flexed-arm hang. For the push-up, both percent body fat and female gender were negatively associated with test score. The only test for which the composite strength score (Sum 1-RM) entered the regression model was the VMPU test, and body fatness also entered in this model. The composite endurance score (SumEnd) failed to enter in any model.

Forward stepwise regression analysis was used to generate models that explained the greatest fractions of variance in performance on each field test. Results of these analyses are summarized in Table 5. Percentages of variance in field test scores explained by the models ranged from 25 to 50%. It is important

Table 3

Zero-Order Correlations Between Independent and Dependent Variables (log transformed)

	Pull-ups	Vermont modified pull-ups	New York modified pull-ups	Flexed-arm hang	Push-ups
Age	.03	.04	.07	.10	.11
Gender	–.21*	–.21*	–.23*	–.11	–.44*
Height	–.26*	–.35*	–.23*	–.32*	–.17
Weight	–.32*	–.51*	–.36*	–.61*	–.19
% Body fat	–.52*	–.60*	–.47*	–.66*	–.46*
Physical activity	.01	–.01	–.02	.09	.13
Organized recreation	–.06	–.05	–.01	–.01	.10
Sum 1-RM	.11	.21	.13	–.10	.32
Sum End	.08	.13	.04	.19	.05

*p < .05.

Table 4

Regression Analysis (standardized coefficients)

Independent variables	Pull-ups	Vermont modified pull-ups	New York modified pull-ups	Flexed-arm hang	Push-ups
	Dependent variables				
Age	.08	.06	.14	.20	.05
Gender	−.15	−.06	−.20	−.08	−.26*
Height	−.38**	−.11	−.19	−.11	−.22
Weight	.35	−.37	−.19	−.11	.21
% Body fat	−.62**	−.36*	−.25	−.43*	−.49**
Physical activity	.04	−.17	−.17	−.11	.15
Organized recreation	−.09	−.02	.03	−.11	.02
Sum 1-RM	.02	.40**	.07	.08	.22
Sum End	.09	.18	.12	.18	.10

*$p \leq .05$; **$p \leq .01$.

Table 5

Stepwise Regression With Explained Variances

Independent variables	Pull-ups	Vermont modified pull-ups	New York modified pull-ups	Flexed-arm hang	Push-ups
	Dependent variables				
Age					
Gender	.06*		.05*		.25**
Height					
Weight		.07*			
% Fat	.24**	.35**	.20**	.31**	.09*
Physical activity					
Organized recreation					
Sum 1-RM		.08*			.04*
Sum End					
Model R^2	.30**	.50**	.25**	.31**	.38**

*$p \leq .05$; **$p \leq .001$.

to note that, in every case, percent body fat explained a significant fraction of variance in field test score performance. Gender accounted for significant fractions of variance in the PU, NYMPU, and Push models. The composite strength score (Sum 1-RM) explained a significant fraction of variance only in the models for VMPU and Push. The composite endurance score (SumEnd) failed to account for a significant proportion of variance in any model analyzed. The greatest fraction of total variance in test score performance (50%) could be explained in the VMPU model, which included percent body fat, weight, and Sum 1-RM as independent variables.

Discussion

Test items that are purported to measure upper body muscular strength and endurance are included in virtually all of the physical fitness test batteries currently in wide use in the U.S. (1, 3, 9, 15). Against this background the most notable finding of the present study is that the laboratory measure of upper body muscular strength, sum of three 1-RM tests, failed to enter into regression models or account for significant fractions of variance in performance on four of the five field tests examined. The exception was the Vermont pull-up, with which a highly significant standardized regression coefficient (.40, p=.004) was observed for Sum 1-RM. This finding indicates that about 11% of variance in performance on the Vermont pull-up can be explained by variation in absolute muscular strength, but for the other tests absolute muscular strength explains little of the variance in performance.

The field tests examined in this study also have been purported to measure muscular endurance. However, our criterion measure of muscular endurance failed to enter into regression models or account for significant fractions of variance for any of the field tests examined. It is noteworthy that this variable approached significance in the VMPU and FAH models (p=.052 and .08, respectively).

Also of considerable importance is the observation that percent body fat was significantly and independently associated with performance on the pull-up, flexed-arm hang, push-up, and VMPU tests. These associations persisted after controlling for the effects of body weight, gender, and several other variables. This finding indicates that body fatness is a significant predictor of performance on these four tests and that fatness is better associated with performance on push-up, pull-up, and flexed-arm hang test than are laboratory measures of UBMSE. Furthermore, in stepwise regression models, percent fat explained significant fractions of variance, ranging from 9 to 35% in each of the five field tests examined.

Our results clearly indicate that body fat hinders performance on the tests examined in this investigation. This was expected, since fat acts as dead weight that must be lifted to achieve a successful repetition. What is striking, however, is the magnitude of the observed association. Others have reported associations in the same direction but of lower magnitude. In children in Grades 3 to 5, Engleman and Morrow (6) found that both traditional and modified pull-up performances were negatively related to skinfold thickness (correlations between .30 to .50). Also, Cureton, Boileau, and Lohman (5) found that body composition measures among young boys increased the amount of variance in pull-up score explained, above that explained by age, height, and weight. They concluded that body composition should be considered when interpreting test performances. The results of the present study strongly support that conclusion.

Each field test observed in this study involves movement of body weight or a fraction thereof. Accordingly, it could be hypothesized that body weight would be a predictor of performance on these field tests. Indeed, we have previously reported that performances on these tests are significantly associated with strength *expressed relative to body weight* (13), and Cotten has observed that weight was negatively correlated with modified pull-up performance in children (4). In the present study the zero-order correlations reported in Table 3 indicate that body weight was significantly and negatively associated with performance on each test.

So the results of this study do indicate that greater body weight is associated with poorer performance on the observed tests. However, in interpreting these observations it is important to note that body weight and body composition were significantly correlated (r=.71) and that, in univariate analyses, body composition was more strongly associated with test performance than was body weight. When both variables were entered in multiple regression models, body composition remained a significant predictor of test performance but the effect of body weight was not statistically significant. This observation, we believe, indicates that body composition remains a significant predictor of test performance after controlling for variance in body weight.

These observations are plausible because weight tends to be highly correlated with lean body weight (r=.91 in the present study), and lean weight should be well correlated with absolute strength (r=.71 in this study). Therefore, in the present study fatter subjects were at a disadvantage, even after controlling for the effect of body weight, but heavier subjects were not at a disadvantage after controlling for the effect of body composition.

Regression analyses revealed some other interesting relationships. Height was significantly related to score on the pull-up test, such that taller subjects had poorer performances. Fleishman (7) found a similar relationship in 18-year-old males. A possible explanation for this finding could lie in the observation that, in our study, arm length was significantly correlated with height (r=.86, p<.0001). A successful pull-up repetition requires that the center of gravity be raised vertically until the chin is over the bar. The longer the arms, the greater the distance moved and the more work required for each repetition. It is likely that greater height (and greater arm length) failed to hinder other field test performances because the vertical distance the center of gravity moved was less on these tests than on the pull-up.

Another interesting finding was that female gender was negatively associated with push-up score. In this investigation all subjects performed push-ups with only their toes and hands in contact with the floor. However, in practice many test administrators alter the protocol for girls, allowing them to place the knees on the floor. It may be that the novelty of the test, or motivational factors, contributed to poorer performance among the girls.

Stepwise regression analyses revealed that, in general, the fractions of variance that could be accounted for by the available set of independent variables were quite low. The test for which the greatest variance could be explained was the VMPU, in which percent body fat, strength, and weight accounted for 50% of the variance in performance. These results indicate that a significant fraction of variance in test performance is associated with variables other than those examined in this study.

A number of limitations may help explain these findings. First, motivation probably plays an important role in performance of tests such as those observed in this study. In the present study attempts were made to motivate the subjects in a consistent manner, but the motivational state of the subjects was not measured. Second, although tests were demonstrated prior to administration, skill and experience do affect fitness test performance. These variables were not measured in the present study. Third, we feel our measures of physical activity behavior were not specific to activities that would affect upper body strength, and this may explain the failure to observe a significant effect of physical activity on performance. All of these factors, and perhaps others not measured, may have led to the low explained variances seen in this study.

In conclusion, the results of this study indicate that performance on common field tests of upper body muscular strength and endurance are, in general, poorly associated with laboratory measures of muscular strength and endurance. In contrast, percent body fat was a significant predictor of performance on four of the five tests observed. Clearly, if field measures of upper body muscular strength are to be included in youth fitness test batteries, there is a need to better understand the physiological and behavioral factors that determine performance on such tests. Accordingly, we recommend that studies like the present one be replicated with larger numbers of subjects, different age groups, and validated measures of habitual activity behavior. In addition, the determinants of performance on test items other than those studied here should be explored.

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