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MEASUREMENT OF ISOMETRIC STRENGTH IN AN UPRIGHT PULL AT 38 CM

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

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A procedure and device to measure an isometric upright pull at 38 cm is described. The test was originally designed to be used in the prediction of lifting capability. The equipment includes an electronic load cell (transducer), a mounting platform and a visual readout. The test consists of a maximal voluntary isometric pull from a squatting position and involves a critical point in the range of motion as well as many of the same muscle groups involved in lifting an object from ground level. For a sample of

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MEASUREMENT OF ISOMETRIC STRENGTH IN AN UPRIGHT PULL AT 38 CM

by

Joseph J. Knapik, James A. Vogel and James E. Wright

Project Reference: 3E162777A845

US Army Research Institute
of Environmental Medicine
Natick, MA 01760

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FOREWORD

During the meeting of the NATO Research Study Group on Physical Fitness (Mainz, Germany 23-26 Sep 80), a multiple regression formula for the prediction of lifting ability was presented (see Appendix), and the procedures used to develop this equation have been detailed in another report (15). This regression formula included the factors of lean body mass, gender and an isometric strength measure of upright pull force. While the estimation of lean body mass (calculated from % BF) has been well described in the literature (5) the isometric upright pull is not as well known. It is the purpose of this article to present in some detail the procedures and equipment employed for this test as well as present descriptive statistics from a sample of young men and women.

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Abstract

A procedure and device to measure an isometric upright pull at 38 cm is described. The test was originally designed to be used in the prediction of lifting capability. The equipment includes an electronic load cell (transducer), a mounting platform and a visual readout. The test consists of a maximal voluntary isometric pull from a squatting position and involves a critical point in the range of motion as well as many of the same muscle groups involved in lifting an object from ground level. For a sample of young male and female soldiers the procedures were shown to have a reliability coefficient of 0.97 over three trials. The mean (± S. D.) values were 138 ± 24 kg and 84 ± 19 kg for males and females respectively.

Introduction

The 38 cm isometric upright pull test was developed as a possible predictor of the ability to perform tasks involving lifting type movements. The start of an actual lifting task is a critical point in the lift. Here the inertia of the load must be overcome and, depending on the posture adopted, the body position could be less than optimal. The 38 cm location is near this critical point in the movement. Also the subject positioning on the test is similar to the initial stage of a lifting movement so that similar muscle groups are involved. No correction is made for body size since in an actual lifting task a fixed load must be lifted regardless of body size.

The test is a modification of one mentioned by several authors (3,4,12). Chaffin (3) has described both a "leg lifting strength test" and a "torso lifting strength test". The latter test was considered dangerous because the marked kyphosis that could develop during a maximal effort was deemed to have a high potential for injury. An adaptation of the leg lifting strength test was developed for the present purposes with modifications especially in the handle portion of the device.

Description of Equipment

The equipment required for the test is shown in Figures 1 and 2. The base platform, measuring 79 x 61 cm is constructed from 1.9 cm (3/4 in) plywood and is slightly elevated from the ground by supporting studs. The two sides of the platform are covered with an anti-slip surfacing. The transducer used to measure the applied force is housed in an aluminum cage measuring 7.6 x 7.6 x 10.2 cm and is secured to the platform by 7 "through" bolts attached to a metal plate under the base platform. It is open on one side so the transducer can be

FIGURE 1. SUBJECT POSITIONING AND EQUIPMENT FOR THE 38CM ISOMETRIC UPRIGHT PULL.

easily inserted and removed. The transducer is connected by a fabricated iron hook to a number 41 chain and the chain, in turn, is connected by a swivel joint to the handle. The handle is a piece of 3.2 cm aluminum tubing, 46 cm in length padded with adhesive tape. The distance from the base platform to the center of the handle is 38 cm.

The transducer itself (Figure 2A) is a Baldwin, Lima Hamilton, Corp. (BLH, Waltham, Massachusetts) C2M1 load cell. It has a range from 0 to 454 kg. The indicator (Figure 2B), from the same company, is a Model 450. It has a "peak and hold" circuit that displays the highest force recorded in a single effort by a subject. Specifications for these two components are shown in Table 1.

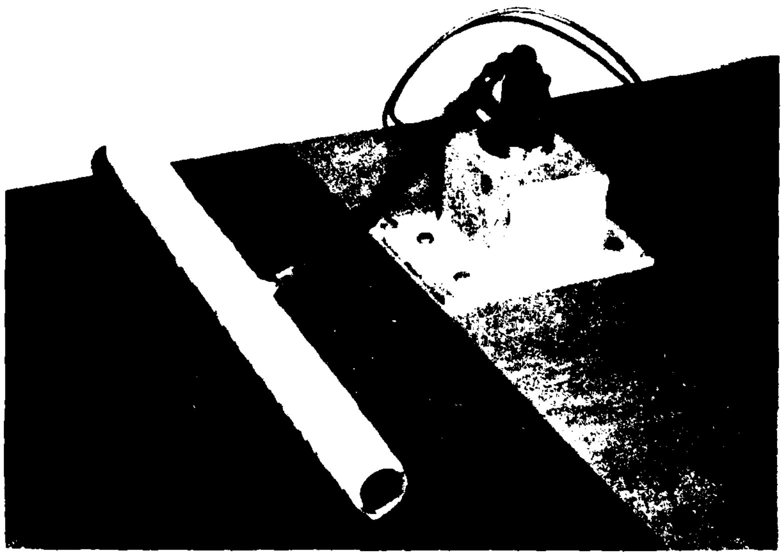
Table 1. Specifications of the BLH C2M1 Transducer and BLH Model 450 Transducer Indicator

C2M1 Transducer	
Rated Output (RO) (mV/V)	2 ± 0.25%
Nonlinearity (%RO)	0.15
Hysteresis (%RO)	0.10
Recommended Excitation (Volts)	12 ac-dc
Maximal Excitation (Volts)	18 ac-dc
Safe Overload (% RO)	150
Model 450 Transducer Indicator	
Min Input Level (mV/V)	± 0.5
Max Input Level (mV/V)	± 3.0
Output Level (Volts)	± 5 at 2.5mA
Max Frequency Response	3dB down at 8 kHz

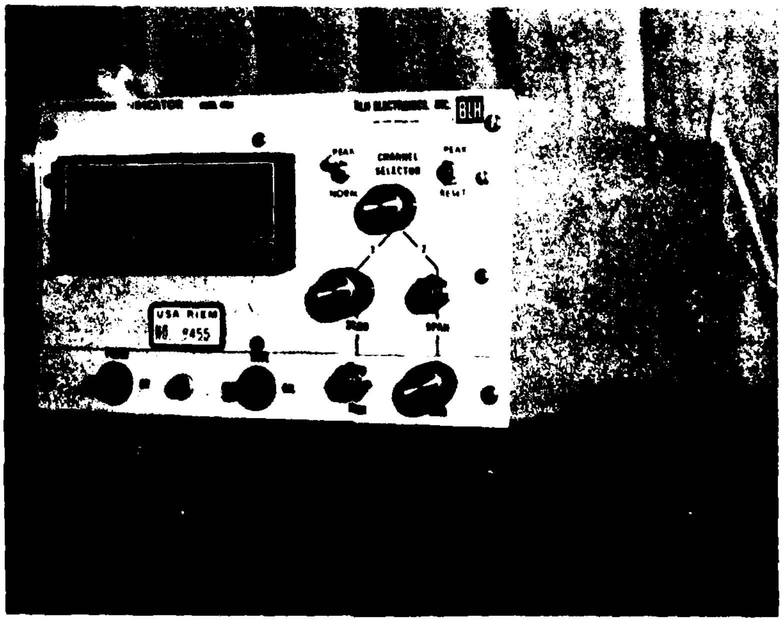
Description of the Test and Subject Positioning

Subject positioning for the 38 cm upright isometric pull test is illustrated in Figure 1. The subject stands with his/her feet about 50 cm apart and squats down, flexing at the knees and hip. He/she grasps the handle with the palms facing in opposite directions approximately equidistant from the center. The

FIGURE 2.



A. PLATFORM & MOUNTING OF FORCE TRANSDUCER



B. TRANSDUCER INDICATOR

subject is instructed to place his/her buttocks against a wall to the rear, straighten his/her back and look straight ahead. The subject is asked to keep the back straight and pull up on the bar as hard as possible, building up to his/her maximal strength as rapidly as possible without jerking. A command of "ready-three-two-one-pull" is given and the subject holds the contraction for about five seconds. The movement involves primarily a combination of hip flexion, knee and trunk extension and shoulder elevation.

Note in Figure 1 that the chain is not perfectly vertical but rather is at an angle to the vertical. The transducer is designed to measure forces only in the vertical direction. Thus in the case in Figure 1, a vector component of the force exerted by the subject would be measured rather than the true force. The true force could be calculated by dividing the value recorded on the indicator by the cosine of the angle between the vertical and the chain (16). However, this problem is avoided if the tester insures at the start of the test that the chain is in the vertical position.

Reliability and Descriptive Data

A sample of subjects was tested at Ft. Stewart, Georgia in September and October of 1979. The data obtained from this study were used to estimate the reliability of the 38 cm isometric upright pull and to provide some descriptive statistics.

Methods

A sample of 221 males and 49 females, assigned to a wide variety of military occupational specialities at Ft. Stewart, Georgia, were tested. Subjects were volunteers who had given their informed consent to participate in the study. These subjects were many of the same individuals used to develop the equation presented in the appendix plus some additional ones. The procedures and equipment described above were used.

Three trials were given to each subject. If a trial was improperly performed, it was repeated up to a maximum of five trials and the three highest scores were recorded. Weight and height were measured with subjects in their stocking feet wearing fatigue pants and T-shirts. Percent body fat was estimated from four skinfolds using the equations of Durnin and Wormersley (5) and lean body mass was calculated from percent body fat.

Results

Table 2 contains the physical characteristics of the sample. The standard deviations are small, indicating the sample was relatively homogeneous with respect to these variables.

Table 2. Physical Characteristics of the Subjects (Values are Means ± Standard Deviations)

	Age (yrs)	Ht (cm)	Wt (kg)	BF (%)	LBM (kg)
Males (N = 221)	21.1 ± 2.3	176.1 ± 6.5	73.6 ± 8.6	15.3 ± 4.1	62.2 ± 6.2
Females (N = 49)	22.7 ± 2.8	165.9 ± 6.3	63.5 ± 9.8	27.9 ± 5.6	45.5 ± 5.8

Table 3 depicts the mean values, standard deviations and the maximum and minimum values obtained for the three trials on the upright pull. Note that a greater number of males were tested on the physical characteristics than on the upright pull. A repeated measures analysis of variance (ANOVA) was performed on the three trials (1). As shown in Table 3, the resulting F-values (df = 2,980 for males and 2,424 for females) were not statistically significant either for the males or females.

Table 3. Descriptive Statistics and ANOVA for the Three Trials Given on the 38 cm Isometric Upright Pull (Trial Values in kg)

		Trial 1	Trial 2	Trial 3	F-Value
Males (N = 214)	Mean	139.2	138.1	137.6	2.78
	SD	25.3	25.1	24.2	
	Max	196.0	206.0	205.0	
	Min	51.0	56.0	58.0	
Females (N = 49)	Mean	83.6	82.7	84.9	1.69
	SD	18.9	19.9	19.3	
	Max	129.0	134.0	135.0	
	Min	54.0	46.0	42.0	

Reliability was estimated using intraclass correlational techniques (8,13) that allow partitioning of the variance into so called "true" variance (variance among subjects or inter-individual variance) and "error" variance (variance among trials or intra-individual variance). In Table 4 the variance has been partitioned into these two components. The values for males and females are identical and more than 90% of the variance is due to differences among subjects while less than 10% is due to trial to trial variations. The reliability coefficients ("R-Value" in Table 4) are acceptably high.

FIGURE 3. HISTOGRAM OF MEAN VALUES ON THE 38 cm UPRIGHT PULL FOR MALES AND FEMALES

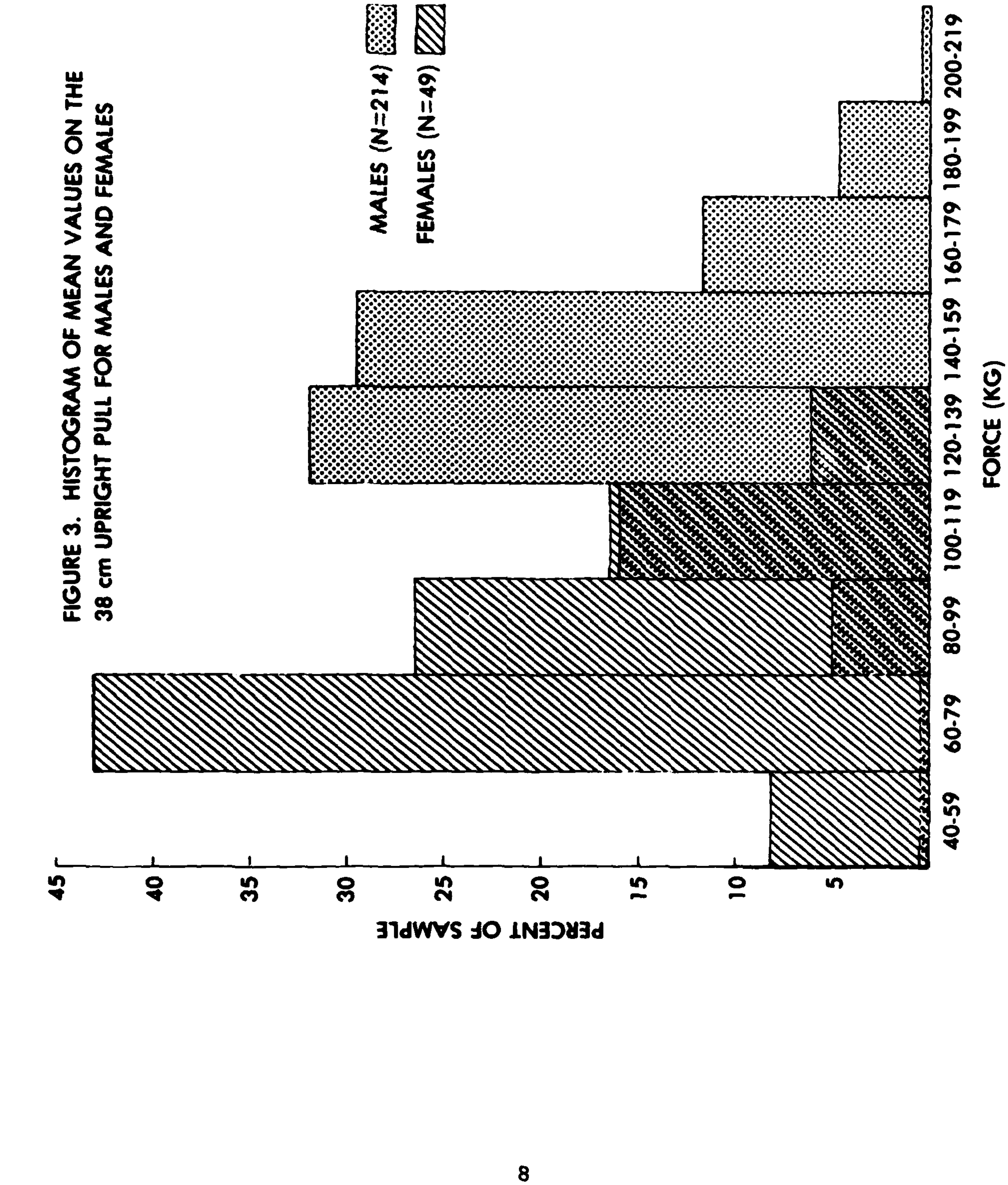


Table 4. Reliability Estimates and Percent of the Total Variance Attributable to Among Subjects and Among Trials Variance

	% Variance		
	Subjects	Trials	R-Value
Males (N = 214)	90.5	9.5	0.97
Females (N = 49)	90.5	9.5	0.97

For each subject the three trials were averaged in order to obtain a criterion strength score. Descriptive statistics on these criterion strength values are shown in Table 5. In Table 6 the percentile rankings of these values are presented while Figure 3 graphically depicts the distibution of scores in 20 kg intervals. The distribution for the males is approximately normal: the mean (Table 5) and the median (Table 6) are about the same. On the other hand the mean value for the females (Table 5) is nearer the sixtieth percentile (Table 6). Thus, there are more females below the mean value than above it. Also note that the highest female value is lower than the fortieth percentile value of the males.

Table 5. Descriptive Statistics for Males and Females on the 38 cm Isometric Upright Pull (Values in kg)

	Mean	Standard Deviation	Standard Error	Maximum Score	Minimum Score
Males (N = 214)	138.1	24.4	1.7	202.3	55.0
Females (N = 49)	83.7	18.7	2.7	131.3	49.3

Table 6. Percentile Rankings of Males and Females on the 38 cm Isometric Upright Pull (Values in kg)

Percentile	Males (N = 214)	Females (N = 49)
1	84.3	49.3
2	89.3	49.3
5	96.7	57.3
10	107.7	62.3
20	116.7	69.7
25	122.7	72.0
30	126.3	73.3
40	131.7	76.3
50	138.0	79.3
60	145.3	83.3
70	151.3	90.7
75	155.3	91.3
80	157.7	103.7
90	168.7	111.7
95	180.3	121.3
98	189.0	131.3
99	189.3	131.3

Discussion

Because of the large inter-individual differences observed it would appear that the isometric upright pull task has a relatively high ability to discriminate among subjects on the basis of their maximum voluntary strength. The high reliability estimate suggests that the values obtained on one trial will be similar to those obtained on another trial. The ANOVA (Table 2) indicates that the error variances are random, uncorrelated and independent (6,14). When this is the case several authors (2,7,11) have suggested that the criterion strength value should be the mean of all available scores. Thus, for the percentile ranking in Table 6 and for the histograms in Figure 3 the mean values for the three trials have been used.

It is difficult to make direct comparisons of the values obtained in this study with those of other studies because of differences in instruction, equipment, methodology and biomechanics. No studies have been found that have measured maximum vountary strength with the same subject positioning as that of the present study. Churchill et al. (4) did perform an almost identical test for females except that subjects were instructed "to minimize pull with (their) back" and the actual test more closely resembled Chaffin's "torso lifting strength test" (3) than the present test. Furthermore, the mean value reported by Churchill et al. (4) amounted to only 78% of that recorded in the present study.

Hettinger (9) has reported that the muscle strength of women was about two thirds that of men. There were, however, considerable variations depending on the muscle group involved. Women had only 55% the strength of men in the forearm flexors and extensors, 60% in the trunk flexors and extensors and 80% the strength of men in the hip flexors and extensors. Laubach (13) in a review of nine studies on the comparative muscle strength of men and women reported that this range was from 35% to 86% with an average of 63.5%. Knapik et al. (10) measured the muscle strength of three major muscle groups (upper torso, legs and trunk extensors) for a larger sample of men and women. The strength of women, calculated as an average from these three muscle groups was 62.4% that of men. The value obtained in the present study was 60.8% which compares favorably with those cited above.

Epilogue

The 38 cm isometric upright pull test appears to be a reliable procedure with which to measure maximum voluntary strength. The usefulness of this test for the prediction of lifting capacity has been demonstrated in another study (15). No studies have been performed however that have examined the stability of the test scores over a number of days and this could probably be the next step in the development of this test.

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Appendix

ASSESSMENT OF MUSCLE STRENGTH AND LIFTING ABILITY UPON ENTRY INTO THE SERVICE. J. A. Vogel, J. E. Wright and D. S. Sharp. US Army Research Institute of Environmental Medicine, Natick, MA 01760, USA.

The objective of this research was to identify physical or physiological indicators that could be simply administered at the time of entry into the service which would be predictive of ability to perform occupational lifting tasks. This predicted lifting capacity would be utilized for occupational qualification and assignment. The first step was to identify a single lifting criterion task that would generalize to a wide variety of actual lifting tasks. Maximum lifts and various repetitive lift and carry tasks were considered and the maximum safe lift to a height of 132 cm was chosen. This measurement was performed with incrementally increasing lifts of a weighted box to a 132 cm platform. For predictor variables, various anthropometric measures as well as isometric measures of muscle strength of several muscle groups were evaluated for their ability to predict the criterion variable of lifting capacity (MLC). With practical considerations of measurement in mind, the measurements of lean body mass (LBM) by the skin fold technique and an isometric upright pull force (UP) at 38 cm (Fig. 1) proved to be the most suitable. The following equation was constructed: $MLC = -8.5 + 0.99\ LBM + 0.01\ UP - 4.7G$ where G refers to an adjustment for gender. Resulting multiple correlation coefficient was 0.78. Mean $\pm$ SD MLC for females ($n = 41$) was 32.6 ± 5.5 and 57.4 ± 9.9 for males ($n = 181$).

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