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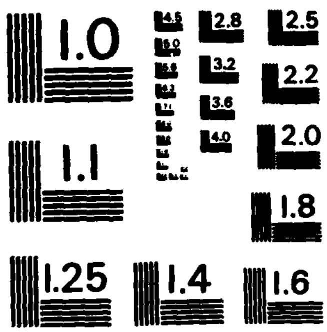

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A large influx of women into traditionally male fields of employment has drawn much attention to the strength differences between men and women. Two tests of isometric strength (handgrip and upright pull) and two tests of maximum lift capacity (a weight lift machine-IDL 152 and a weighted box lift MLC 132) were administered to 90 male and 107 female soldiers at the end of their Basic Training in order to examine differences in female/male (F/M) strength ratio. Skinfold measurements were made to obtain an estimate of lean body mass (LBM). Females exhibited 63% of the isometric strength and 55-59% of the lifting (cont)

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) capacity of males. When the scores were normalized for body weight (BW) females were 75% as strong as males on isometric measures, and were able to lift 66% as much on IDL 152 and 72% as much on MLC 132. When normalized for LBM the F/M ratio improved to 86% for isometric strength, 75% for IDL 152 and 82% on MLC 132. It is apparent that a number of factors, other than LBM, are responsible for gender differences in strength. Comparison of the two lifting tasks revealed that on the average, males were able to lift 18% more weight and females 24% more weight on the free lift than on the machine lift. This would suggest that if a machine lift is used for pre-employment screening purposes, the absolute weight an applicant is required to lift on the machine need not equal the maximum weight to be lifted on the job. As the difference between a machine lift and a free lift task was greater in females, a machine lift test may pose a greater disadvantage to female candidates than would isometric or free weight lift testing.

HUMAN RESEARCH

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

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Comparison of Male and Female Maximum Lifting Capacity

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Abstract

A large influx of women into traditionally male fields of employment has drawn much attention to the strength differences between men and women. Two tests of isometric strength (handgrip and upright pull) and two tests of maximum lift capacity (a weight lift machine-IDL 152 and a weighted box lift MLC 132) were administered to 90 male and 107 female soldiers at the end of their Basic Training in order to examine differences in female/male (F/M) strength ratio. Skinfold measurements were made to obtain an estimate of lean body mass (LBM). Females exhibited 63% of the isometric strength and 55-59% of the lifting capacity of males. When the scores were normalized for body weight (BW) females were 75% as strong as males on isometric measures, and were able to lift 66% as much on IDL 152 and 72% as much on MLC 132. When normalized for LBM the F/M ratio improved to 86% for isometric strength, 75% for IDL 152 and 82% on MLC 132. It is apparent that a number of factors, other than LBM, are responsible for gender differences in strength. Comparison of the two lifting tasks revealed that on the average, males were able to lift 18% more weight and females 24% more weight on the free lift than on the machine lift. This would suggest that if a machine lift is used for pre-employment screening purposes, the absolute weight an applicant is required to lift on the machine need not equal the maximum weight to be lifted on the job. As the difference between a machine lift and a free lift task was greater in females, a machine lift test may pose a greater disadvantage to female candidates than would isometric or free weight lift testing.

1. Introduction

Many attempts have been made to isolate the factors responsible for male - female strength differences. While researchers have compared the isometric (Montoye and Lamphaier,1977), isotonic (Wilmore,1974), and isokinetic (Hosler and Morrow,1982) strength of males and females in both absolute terms and relative to body size, few have compared lifting ability. The data that are available generally involve submaximal repetitive lifting or isometric lifting strength. A few studies that are directly applicable are based on a small number of subjects. Yates et al (1980) reported female/male ratios of 33% and 50% for isometric lifting (pulling) strength above and below waist level. Pytel and Kamon (1981) reported a female/male ratio of 46% for 10 males and 10 females on a dynamic box lift, which had been previously reported to have a ratio of 66% for 4 males and 4 females (Jorgensen and Poulsen, 1974). The purpose of this study was to compare the maximum lift capacity and isometric strength of a large sample of males and females, expressed absolutely and relative to body weight (BW) and lean body mass (LBM). A secondary purpose was to compare two types of lifting tasks used for occupational screening: a machine lift and a free weight lift.

2. Methods

2.1 Subjects

Ninety males and 107 females were tested at the end of a standard 8 week Army Basic Training program. The means ± SD for age, height, weight, percent body fat and LBM of the males and females, respectively, were 19.4±2.3 and 20.2±3.5 yrs, 175.2±6.1 and 162.7±6.2 cm, 73.5±7.6 and 61.2±6.3 kg, 14.0±3.3 and 24.3±3.4% and 63.0±5.7 and 46.2±4.1 kg.

2.2 Maximum Lift Capacity

The two measures of lifting capacity made were maximum incremental dynamic lift to 152cm (IDL 152), and maximum lift capacity to 132 cm (MLC 132). IDL 152 described by McDaniels,(1983) was a machine lift of a weight stack to a height of 152 cm. The weight stack could be adjusted from 18.1 kg-90.9kg.The subject started the lift in a bent knee, straight back position and was instructed to drive upward with the legs, turn the wrists under the bar handle and press the weight up to 152 cm. The IDL machine and correct lifting technique are illustrated in Figure 1. Following each successful lift, the weight was increased by 4.5 kg for females and 9.0 kg for males. When males began to show difficulty lifting the weight, the weight increment was decreased to 4.5 kg. The subject continued lifting without rest until he/she failed to raise the weight to
152 cm.

MLC 132 was a free lift of a weighted box (45cm X 31cm X 26cm) to a 132 cm platform. The empty box weighed 15.2 kg, and weights ranging from 1.2-11.0 kg were used to increase the load. The weight increase was based on the subjects' performance. An experienced technician was usually able to obtain the subject's MLC 132 within 5-7 lifts. In order to make MLC 132 equivalent to IDL 152 the maximum load lifted was 90.9 kg and the box handles were 20 cm above the box bottom, which resulted in a box handle height of 152 cm when the box was placed on the platform. Safe lifting technique was emphasized for both lifts, and the final score was the weight of the last successfully completed lift in kilograms.

2.3 Isometric Strength

Isometric hangrip (HG) strength was measured as described by Ramos and Knapik (1978).The subject was seated with forearm resting on a padded table surface to which the HG device was firmly attached. The apparatus was adjusted to provide an angle of 150^{o} at the third metacarpalphalangeal joint and 110^{o} at the proximal interphalangeal joint of the third finger of the right hand. The tension was measured by an electronic load cell and a digital readout of peak force was obtained from a transducer indicator.

The 38cm UP test described in detail by Knapik et al, (1981) was similar to Chaffin's leg lifting strength test (1975). The device consisted of a taped aluminum bar attached by airplane cable to a load cell mounted on a slip-proof wooden platform. Output from the load cell was digitally displayed on a transducer indicator. The vertical distance from the platform to the horizontal axis of the handle was 38cm. Subjects straddled the load cell in a semi-squat position with the legs shoulder width apart, the arms and back straight, the head up and the bar held in a mixed grip. For both isometric tests, subjects were instructed to build to maximum force over 1-2 seconds and hold the contraction for 3 additional seconds. A one minute rest period was allowed between trials. The peak value from seconds 3-5 was accepted as the maximum isometric strength. The final score was the mean of three trials within 10% of one another.

2.4. Body Composition

The method used was that of Durnin and Womersley (1974). Harpenden calipers were used to make three measures at each of four sites (biceps, triceps, subscapular and suprailliac). The sum of four mean skinfolds was used to estimate percent body fat from which lean body mass (LBM) was derived.

2.5 Procedures

All measures were made within a four hour period. The order of testing was varied with a minimum of 5 minutes rest between measures.

3.0 Results

The absolute value, range and female/male ratio (F/M) of the isometric strength and maximum lift capacity measures are shown in Table 1. In all cases males were significantly stronger ($p<.01$) than females. Females exhibited 63% of the isometric strength and 55-59% of the lifting capacity of males. The male and female strength scores normalized for BW and LBM and the resulting F/M ratios are presented in Table 2. Normalization for BW increased the F/M ratio by at least 10% for each measure, and females were able to match 75-86% of the male strength when scores were normalized for LBM. While normalization for BW and LBM greatly reduced the male-female strength differences, males continued to produce significantly more force and lift more weight ($p<.01$) than females. The two isometric strength measures yielded identical F/M ratios when normalized for BW and LBM and were slightly greater than the normalized F/M ratios obtained for MLC 132. The IDL 152 F/M ratio was consistently lowest in both absolute and normalized terms.

Table 1 Isometric Strength and Lifting Capacity of Males and Females (Mean ± SD and Range) and the Female/Male Ratio (F/M)

	Male			Female			F/M
	Mean	SD	(Range)	Mean	SD	(Range)	(%)
n		90			107		
Handgrip (kg)	52.7 ±	7.8	(35.5 - 69.7)	33.0 ±	4.9	(21.7 - 47.4)	63
38cm UP(kg)	142.2 ±	21.4	(97.3 - 200.0)	89.0 ±	19.3	(55.3 - 126.3)	62
IDL 152 (kg)	63.0 ±	9.9	(40.9 - 90.9)	34.7 ±	8.2	(22.7 - 54.5)	55
MLC 132 (kg)	77.1 ±	24.5	(35.6 - 90.9)	45.8 ±	21.1	(20.8 - 90.9)	59

Table 2 Isometric Strength and Lifting Capacity of Males and Females Normalized for Body Weight and Lean Body Mass (Mean ± SD)

	Male	Female	F/M (%)
n	90	107	
Handgrip/BW	0.72 ± 0.10	0.54 ± 0.08	75
Handgrip/LBM	0.84 ± 0.10	0.72 ± 0.09	86
38 UP/BW	1.94 ± 0.24	1.46 ± 0.31	75
38 UP/LBM	2.25 ± 0.25	1.93 ± 0.40	86
IDL 152/BW	0.86 ± 0.11	0.57 ± 0.13	66
IDL 152/LBM	1.00 ± 0.12	0.75 ± 0.17	75
MLC 132/BW	1.04 ± 0.32	0.75 ± 0.34	72
MLC 132/LBM	1.21 ± 0.37	0.99 ± 0.45	82

4. Discussion

Hosler and Morrow (1982) found LBM accounted for the greatest amount of variance in male-female strength differences. They suggested that females should train and eat more to increase LBM thereby decreasing female to male strength differences. In the present study, females were still 15-25% weaker than males when the scores were normalized for LBM. While muscle mass is only one component of LBM and normalization for pure muscle mass might improve the F/M ratio, it is likely that other factors also play a role in the demonstrated strength differences.

The isometric strength measures produced a greater F/M ratio than did lifting capacity measures. In a review of the literature, Laubach (1976) reported that females have approximately 72% of the lower body strength of men, but only 56% of the upper body strength. Of the two measures selected, 38cm upright pull is heavily dependent upon the lower body and handgrip involves only a small amount of muscle mass. Most test subjects had no experience with isometric exercise, therefore males and females were at an equal disadvantage. The measures selected and the lack of familiarity to both sexes may have enabled females to better approximate the isometric strength than the isotonic strength of their male counterparts.

Females were able to lift 82% of the weight lifted by males on MLC 132 when normalized for LBM, and 72% when normalized for BW. Two previous studies used a measure similar to MLC 132 and reported BW, but did not report LBM. Pytel and Kamon (1981) reported substantially lower values for maximum dynamic lift capacity than the present study and an absolute F/M ratio of 46% which improved to 57% when expressed relative to BW. Pytel and Kamon did not require performance of more than one complete lift, and therefore could not be sure of obtaining a true maximum. The maximum lifting capacity reported by Jorgensen and Poulsen (1972) was 10% greater than the males and 19% greater than the females in the current study, however the lifting height was substantially lower (63 cm for men and 59 cm for women). The F/M ratio of the Jorgensen and Poulsen sample was 66% in absolute terms and 79% when normalized for BW. The F/M ratio normalized for BW of 72% in the present sample is within range of the other studies mentioned, and is based on a much larger population. The descriptive measures and the absolute isometric strength measures of the present study are comparable to those obtained for similar groups of males and females (Keyserling,et al,1980, Wilmore, 1974). Therefore, a good approximation of the F/M ratio of a free lift similar to MLC 132 in a young healthy population would be 60% in absolute terms, 70% relative to BW, and 80% relative to LBM. For this same population the maximum weight an average male should be expected to lift once is a load equal to his body weight while an average female should be able to lift 75% of her body weight to a 132 cm height.

The maximal value achieved on IDL 152 was 18% lower than on MLC 132 in males and 24% less in females. This was surprising, as both required subjects to lift the weight to the same height. Serious weight trainers contend that free weights are far superior to a machine weight training device because it allows the athlete to train the entire muscle and to change the immediate site of fatigue with slight variations in lifting technique. While performing MLC 132, subjects may have been able to vary their technique to exert maximum lifting force on the weighted box (MLC 132) with each lift. As the IDL 152 is a stationary machine with tracks to control weight movement, subjects may have had little opportunity to change their technique sufficiently to elicit peak lifting force during each attempt. A second possibility is that the box lift was a more familiar movement to the majority of the subjects, enabling them to perform it more effectively.

Not only were both sexes able to lift more on MLC 132, the F/M ratio was also greater than for IDL 152. A possible explanation for this is that while females have some experience lifting boxes and other objects, traditionally they have had little weight training experience. The IDL 152 is similar to an Olympic lifting maneuver in that the initial impetus to move the weight comes mainly from the legs. When the weight reaches chest height the wrists are snapped beneath the handles and the weight is pressed overhead stressing the upper body musculature. Although the final height of lift is the same, the technique of the two lifts was very different. The required upper body strength and lack of proper technique may have put females at a disadvantage compared to males on IDL 152.

The difference found between the machine and free weight lift has implications for industrial pre-employment strength testing. In this case the average male and female tested on the IDL 152 screening device would be able to lift as much as 18% and 24% more, respectively, in an actual materials handling situation. While the IDL 152 testing device is safe and easily implemented, care should be taken to ensure that the values are adjusted to the actual lifting demands of the job, and that any sexual bias be corrected.

Summary

1. Females were better able to match their male counterparts on isometric than on isotonic tests. The isometric F/M ratios were 63% in absolute terms, 75% normalized for BW and 86% normalized for LBM.

2. Although an attempt was made to equalize two different lifting tasks, most subjects were able to lift more on a weighted box free lift (MLC 132) than on a machine lift (IDL 152). This ability to lift more weight on a free lift was more pronounced in females (24%) than in males (18%), resulting in a greater F/M ratio for the free lift than for the machine lift.

3. As the F/M ratio is greatly influenced by the type of test performed and since two seemingly equivalent lifting tasks yield different results, care should be taken in the selection of strength and lifting screening tests to provide a realistic assessment of job performance capacity.

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