COMPARISON OF LIFTING CAPABILITIES OF INDUSTRIAL AND NON-INDUSTRIAL POPULATIONS

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ABSTRACT

The major objectives of the work presented here were to determine the differences between lifting capabilities of industrial and non-industrial populations by collecting experimental data under identical conditions and to quantify the patterns of such differences. Using the psychophysical approach, male and female industrial and non-industrial workers performed 36 variations of manual lifting task. The major findings of the study were: (i) generally the responses of non-industrial workers to task variables is very similar to the responses of industrial workers, (ii) overall, the lifting capability of non-industrial workers is significantly lower than the lifting capability of industrial workers.

INTRODUCTION

Scientific investigations frequently rely upon student (non-industrial) volunteers who participate in the experiment as subjects (Garg, 1976; Ayoub and El-Bassoussi, 1976; Garg and Saxena, 1979; Asfour, 1980; Mital and Ayoub, 1981; Garg and Saxena, 1981; Mital and Manivasagan, 1983; etc.). The reasons for using inexperienced student volunteers are varied - (i) ease of availability and recruitment, (ii) lower cost, and (iii) greater reliability. Even though none of these reasons is compelling, reliance upon student volunteers is routine.

The experience and age of industrial workers, however, clearly separate them from inexperienced students. One can argue, therefore, that the results of investigations involving inexperienced and young students should not be applied straight away to the industrial population unless it is clearly established that the capabilities of the two populations are not significantly different.

Several previous investigations of manual materials handling activities have in fact indicated large differences between the capabilities of industrial and non-industrial workers (Snook and Ciriello, 1974; Mital and Manivasagan, 1983; Mital and Ilango, 1983). Some investigations also suggest that the response patterns of industrial and non-industrial workers to task variables in manual lifting activities are similar (Mital and Manivasagan, 1983; Garg and Saxena, 1979). Comparison of data from many different studies, on the other hand, tends to indicate no capability differences between industrial and non-industrial populations (Mital, 1985).

The above controversy must be resolved. Moreover, if the inferences drawn on student subjects are to be extended to the industrial population, the nature of the relationship between the manual lifting capabilities of the two populations must be known.

This investigation was undertaken to determine and quantify the differences between the lifting capabilities (maximum acceptable weight of lift) of experienced industrial and inexperienced student populations, based on frequency of lift, height of lift, box size and work duration, by collecting data under identical experimental conditions.

METHODS

Maximum acceptable weight of lift data were collected on industrial and student workers under identical experimental conditions. The data collected on industrial workers have been reported in detail elsewhere (Mital, 1984a,b). Identical procedures were employed to collect data on inexperienced students.

Thirty-seven male and 37 female students, all in good physical health, participated in the study. A personal data sheet was used to screen unhealthy individuals. Anthropometric and strength measurements were made on each subject who finally became a part of the sample population (Table 1).

An incomplete block factorial design was used and each subject randomly performed 9, out of possible 36, treatment combinations (four frequencies - 1, 4, 8 and 12 lifts per minute; three box sizes - 30.48, 45.72, and 60.96 cm long in the sagittal plane; three lifting heights - floor to knuckle, knuckle to shoulder, and shoulder to reach). Each subject, using the psychophysical methodology and a free-style lifting technique, determined the maximum acceptable weight of lift. The heart rate and oxygen uptake of subjects at the maximum acceptable weight of lift were also recorded.

Five males and 5 females, selected at random from the sample population, participated in a separate study conducted for the purpose of validating the psychophysical methodology. Further details of the experimental design and procedure are given elsewhere (Mital, 1983; Mital, 1984a; Mital, 1985).

RESULTS AND DISCUSSION

Isometric Strength Comparison

Four different isometric strength measurements (arm, back, composite, and shoulder) were made on each subject. No significant differences were found between the respective average isometric strengths of industrial males and male students ($p \geq 0.10$). The same was true for females.

With the exception of isometric back and composite strength standard deviations for males, respective standard deviation values were also not significantly different from each other ($p \geq 0.10$). The standard deviations of back and composite strengths for industrial males and male students were only different at the five percent level of significance.

Overall, thus, the strengths of the experienced and inexperienced workers were about the same. It appears that decline in strengths due to aging, in the case of industrial workers, is compensated by experience or time on the job.

Comparison of Response Decrement Trends

The psychophysical methodology was verified on industrial subjects (Mital, 1983) as well as on students (Mital, 1985). In both cases the methodology was not validated. The responses (maximum acceptable weight of lift, heart rate, and oxygen consumption) of both populations declined with time. However, the patterns of decline were different. For industrial males, weight, heart rate, and oxygen uptake declined at the rate of 3.4, 1.9, and 2.6% per hour; for male students the respective declines were 2.6, 1.08, and 2.2% per hour. For industrial females and female students, the corresponding declines in weight, heart rate, and oxygen uptake were 2, 0.8, and 1.9 and 1.9, 0.4, and 3.54% per hour, respectively.

In general, with the exception of oxygen uptake for females, the decline in responses with time were faster for experienced industrial workers than for inexperienced students. Thus it appears that industrial workers overestimate their capability to a greater degree compared to students.

Maximum Acceptable Weight of Lift

Overall, for 8-hour shifts, the lifting capability of male students was 89% of the lifting capability of male industrial workers. The corresponding percentage for females was 94%. For 12-hour shifts, however, the lifting capability of both male and female students was 98% of the respective capability of their industrial counterparts. Tables 2 and 3 show the overall response means and standard deviations of students expressed as a percentage of industrial worker responses.

Table 4 expresses the decline in maximum acceptable weight of lift for various task variables. The decrement in weight with box size was about the same for both populations. At each box size level, the ratio of weight lifted by students and industrial workers was about the same (Tables 2 and 3). For frequency of lift, the decrement in weight for the two populations was the same up to four lifts per minute. Beyond four lifts per minute, decrements for industrial workers were much sharper. The trend for industrial males was similar to the trend for industrial females; the trend for male students was similar to the trend for female students.

In general, the declining trends for industrial males and male students were similar; the declining trends for industrial females and female students were also similar.

The results of this study indicate that experience on the job significantly influences lifting capability of workers and measurement of isometric strengths alone is not sufficient to describe or determine an individual's lifting capability.

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Table 1. Anthropometric and strength measurements of the subject populations.*

	Males			Females		
Variable	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range
Age (years)	24.97 (34.05)	3.41 (10.42)	18-34 (18-61)	23.40 (35.46)	4.61 (9.84)	17-46 (21-58)
Stature	173.60 (172.79)	7.30 (6.60)	158.00-186.00 (155.70-186.80)	162.83 (164.70)	5.21 (6.18)	152.00-172.70 (154.10-176.70)
Body Weight (Kg)	70.18 (81.18)	10.66 (16.66)	49.50- 92.20 (53.57-121.70)	59.90 (69.68)	7.92 (13.78)	45.80- 81.70 (44.13-110.80)
Shoulder Height	143.53 (143.52)	7.10 (6.42)	129.50-156.50 (128.20-157.00)	130.68 (135.42)	14.69 (5.85)	127.40-140.20 (127.20-149.10)
Iliac Crest Height	100.72 (99.23)	5.75 (4.55)	86.70-114.30 (89.10-107.90)	96.47 (97.13)	4.19 (5.59)	86.90-104.20 (85.00-107.80)
Knuckle Height	75.97 (77.63)	5.49 (4.33)	56.10-85.00 (69.00-86.30)	71.15 (72.93)	4.76 (4.04)	50.00-78.60 (65.30-81.90)
Knee Height	50.76 (50.08)	6.36 (3.02)	42.30-84.00 (43.60-56.10)	46.33 (46.64)	3.03 (3.22)	34.80-51.80 (40.20-54.00)
Forearm Grip Distance	37.73 (36.82)	2.42 (2.23)	31.30-42.50 (32.50-41.80)	34.81 (34.61)	3.01 (2.08)	26.40-39.40 (29.80-38.50)
Chest Width	30.36 (32.43)	3.10 (3.87)	20.60-36.20 (22.30-41.50)	27.20 (29.90)	2.83 (2.59)	21.30-34.30 (25.30-35.70)
Chest Depth	20.57 (22.02)	2.61 (3.35)	17.00-29.10 (13.10-28.80)	17.77 (18.96)	2.23 (1.92)	13.70-23.00 (16.20-23.70)
Abdominal Depth	20.38 (22.10)	2.33 (4.27)	15.40-27.60 (13.40-34.60)	18.45 (19.96)	2.40 (3.84)	12.90-23.50 (15.40-31.00)
Arm Strength	35.92 (34.73)	10.46 (10.47)	13.00-57.00 (14.00-61.00)	21.35 (19.03)	6.01 (5.74)	12.00-36.00 (9.00-35.00)
Shoulder Strength	45.03 (44.46)	13.13 (14.48)	23.00- 76.00 (23.00-101.00)	24.40 (22.05)	5.46 (6.85)	13.00-33.00 (11.00-38.00)
Composite Strength	104.24 (99.35)	38.42 (27.98)	36.00-181.50 (55.00-169.00)	60.11 (54.49)	17.11 (16.44)	33.00- 96.00 (28.00-102.00)
Back Strength	60.86 (55.30)	27.60 (19.71)	25.00-128.00 (21.00-116.00)	35.57 (36.00)	8.70 (10.40)	18.00-56.00 (20.00-73.00)

*Numbers in parantheses are for industrial workers (Mital 1984a); Body size measurements are in centimeters; strength measurements are in kilograms.

Table 2. Overall means ($\bar{x}$) and standard deviations (S) of student population responses expressed as a percentage of industrial population responses (8-hour shifts)

		Males		Females	
Variable	Response	$\bar{x}$	S	$\bar{x}$	S
Box size(cm)					
30.48	Weight (Kg)	90	89	95	101
	Heart rate (bpm)	86	66	87	61
	Oxygen uptake ($l.min^{-1}$)	74	66	78	54
45.72	Weight	89	77	94	76
	Heart rate	86	78	90	73
	Oxygen uptake	79	72	76	58
60.96	Weight	89	80	95	76
	Heart rate	87	67	93	76
	Oxygen uptake	79	76	83	62
Frequency (lifts/min)					
1	Weight	85	82	93	98
	Heart rate	94	79	96	85
	Oxygen uptake	95	83	86	56
4	Weight	85	98	93	75
	Heart rate	85	67	92	74
	Oxygen uptake	72	69	75	54
8	Weight	90	81	96	89
	Heart rate	85	78	89	76
	Oxygen uptake	73	84	73	50
12	Weight	99	98	98	87
	Heart rate	82	79	84	83
	Oxygen uptake	77	81	81	64
Height of lift					
Floor to knuckle	Weight	92	85	95	76
	Heart rate	85	61	88	70
	Oxygen uptake	74	75	73	62
Knuckle to shoulder	Weight	86	75	93	89
	Heart rate	84	81	88	72
Knuckle to reach	Oxygen uptake	82	70	74	59
	Weight	90	86	96	103
	Heart rate	91	76	93	70
	Oxygen uptake	79	73	89	62

Table 3. Overall means ($\bar{x}$) and standard deviations of student population responses expressed as a percentage of industrial worker responses (12-hour shifts)

		Males		Females	
Variable	Response	$\bar{x}$	S	$\bar{x}$	S
Box size(cm)					
30.48	Weight (Kg)	99	96	99	108
	Heart rate (bpm)	92	74	89	63
	Oxygen uptake ($l.min^{-1}$)	80	67	70	52
45.72	Weight	97	74	97	76
	Heart rate	91	84	92	73
	Oxygen uptake	83	74	72	57
60.96	Weight	98	83	98	80
	Heart rate	92	78	97	77
	Oxygen uptake	84	76	77	54
Frequency (lifts/min)					
1	Weight	94	90	95	95
	Heart rate	99	95	100	86
	Oxygen uptake	103	94	80	53
4	Weight	94	99	96	80
	Heart rate	91	79	93	67
	Oxygen uptake	77	76	71	45
8	Weight	99	78	100	103
	Heart rate	90	86	91	81
	Oxygen uptake	76	79	68	48
12	Weight	110	97	102	95
	Heart rate	88	84	87	89
	Oxygen uptake	80	74	76	55
Height of lift					
Floor to knuckle	Weight	102	90	98	79
	Heart rate	89	70	91	69
	Oxygen uptake	77	78	68	50
Knuckle to shoulder	Weight	93	73	96	91
	Heart rate	89	90	90	73
	Oxygen uptake	84	69	71	58
Shoulder to reach	Weight	99	91	100	114
	Heart rate	97	86	96	74
	Oxygen uptake	86	74	84	58

Table 4. *Decrement* (%) in the maximum acceptable weight of lift with frequency, box-size, and height level for the student and industrial populations*

	Males		Females	
Variable	Industrial	Student	Industrial	Student
Box-Size (cm)				
30.48	100	100	100	100
45.72	94	93	98	97
60.96	92	91	95	95
Frequency (lifts/min)				
1	100	100	100	100
4	92	92	93	94
8	81	86	82	86
12	70	82	77	83
Height of Lift				
Floor to Knuckle	100	100	100	100
Knuckle to Shoulder	97	90	92	90
Shoulder to Reach	88	86	84	85

*Nearest integer