Progressive Resistance Training Program for Improving Manual Materials Handling Performance

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Occupations such as emergency medical care, fire fighting, and the military involve sudden bouts of high-intensity exertion, which are not performed on a regular or predictable basis. The physical stress of sudden, high-intensity exercise may result in a higher injury rate and diminished job performance in individuals who are not physically prepared. Occupations requiring frequent manual materials handling involve considerable exercise, and novice handlers can be expected to improve performance during the first month of employment simply by performing the task (Genaidy, Mital, and Bafna, 1989; Sharp and Legg, 1988). Once an acceptable level of performance is reached, day-to-day task execution does not provide sufficient physical stress to produce further increases in performance or strength.

Progressive resistance training (or weight training) is generally accepted as an effective adjunct to the practice of technique for improving performance in sports. It follows that an effective training method for physically demanding occupational tasks would be performance of the task, along with supplemental progressive resistance training. Such a training method is not commonly implemented in industrial settings. For workers who perform intense lifting only occasionally, the frequent performance of simulated job tasks, for the purpose of building physical strength would be prohibitively expensive in terms of both resources and time. In addition, the equipment for task-specific training is rarely available to industrial employees. Some corporations provide employees with exercise facilities, but the goal is to improve health not job performance. A program of progressive resistance training using carefully selected exercises may be a practical approach to strength training for physically demanding occupational tasks.

Little information is available to show the effects of progressive resistance training on manual materials handling performance. Asfour and coworkers (1984) utilized progressive resistance box lifting and aerobic training and noted significant increases in strength, aerobic capacity, and one-repetition-maximum box lift following 6 weeks of training. Sharp and Legg (1988) implemented a psychophysical training program in which subjects trained for 4 weeks lifting a box adjusted to the maximum load they estimated they could lift for 1 hour at a rate of 6 lifts.min^{-1}. Psychophysical training increased the box mass lifted for 1 hour. In a group of related studies, Genaidy and colleagues (1989, 1990, 1991) reported increases in task endurance time of 46% to 1200% for a series of manual materials handling tasks. Subjects were trained by performing the task to exhaustion and time to exhaustion served as the performance measure (Genaidy, Mital, and

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Bafna, 1989; Genaidy, Bafna, Sarmidy, and Sana, 1990; Genaidy, 1991). As the greatest improvements in performance are observed when the training and testing modes are identical (Fleck and Kraemer, 1987), it should be noted that these training studies utilized the same equipment and activities for testing and training. The effects of traditional progressive resistance training methods on occupational manual materials handling performance have not been examined. The purpose of this study was to determine if 12 weeks of progressive resistance training is an effective means of improving performance of an occupational lifting task.

MATERIALS AND METHODS

Twenty-five men with minimal manual materials handling experience volunteered to participate in the experiment. Subjects were briefed on the requirements and hazards involved in the study and read and signed a statement of informed consent. None of the volunteers had been involved in a resistance training program within the previous 6 months and all subjects were instructed not to begin any new training procedures. Age, height, and body mass (mean ± standard deviation) were 24.6 ± 5.3 years, 178.6 ± 5.1 cm, and 76.4 ± 12.8 kg, respectively, for the control group (n = 7), and 18.9 ± 1.1 years, 175.7 ± 7.2 cm, and 73.3 ± 10.7 kg, respectively, for the training group (n = 18). Although there was a significant difference in age in the two groups, there were no significant differences in any other pretraining measurement, and age was not a significant covariate. More subjects were placed in the experimental group than in the control group to allow for a potentially greater attrition rate.

Lifting familiarization, subject descriptive measurements, and determination of maximal manual materials handling capacity took place during the 3 weeks preceding the training program. The descriptive measurements and maximal manual materials handling test were repeated following the 12th week of training.

The manual materials handling task was designed to simulate the resupply of a U.S. Army 155-mm Howitzer. Resupply is one of the most physically demanding tasks the field artillery soldier performs and elicits the highest heart rates (Patton, et al., 1991). The crews move as many as 134 projectiles weighing 41 kg each from the supply vehicle to the howitzer in 10 minutes or less. This task can be compared to flood rescue workers piling sandbags, or emergency medical personnel carrying the wounded from a mass casualty scene. The dependent variable for the maximal manual materials handling test was the total number of lifts of a 41-kg box completed in 10 minutes. A floor-to-chest level lift was selected to involve the upper body and to remove the advantage tall subjects have when an absolute lifting height is used. The task was performed on a repetitive lifting machine on which the shelf rose quickly from floor level to chest height when the box was removed from its surface and returned to floor level when the box was replaced on its surface (Teves, McGrath, Knapik, and Legg, 1986). Oxygen uptake, heart rate, and lift rate were recorded continuously. Subjects were instructed to develop an optimal pacing strategy to complete as many lifts as possible during the 10-minute test. A straight-back, bent-legs lifting technique was encouraged but not required. Subjects performed two to three pretraining manual materials handling tests during the initial 3-week period. Adequate lifting-skill acquisition was indicated by the fact that performance on the third pretraining 10-minute test was higher than the second test in only one case, and this was by one lift. The intraclass reliability coefficient was .97 for three trials and .93 for two. The highest test score was selected as the pretraining measure.

Measurements were made to assess the aerobic power, strength, and body composition of the subjects. A repetitive lifting maximal oxygen uptake ($\dot{V}O_2$ max) test was conducted to evaluate the aerobic fitness of the subjects and to describe the relative exercise intensity (percentage $\dot{V}O_2$ max) during the manual materials handling test. Procedures were identical to those previously reported (Sharp, Harman, Vogel, Knapik, and Legg, 1988), except that the lifting height was chest level, to equate with the manual materials handling test.

One repetition maximum lifts, defined as the heaviest loads that could be lifted once, were assessed for bench press, squat, deadlift, and box lift. Maximum box lift was the heaviest load lifted to a chest-high shelf using a box similar to that used during the manual materials handling task (Sharp and Legg, 1988). Body composition was estimated using the hydrostatic weighing method (Fitzgerald et al., 1988). Residual lung volume was measured just prior to underwater weighing using the closed circuit oxygen rebreathing technique (Wilmore, Vodak, Parr, and Girandola, 1980).

The experimental subjects (n = 18) participated in a 12-week progressive resistance training program 3 days per week (Monday, Wednesday, and Friday) and executed 10 exercises in random order. The free-weight exercises used were bench press, deadlift, squat, bent-knee sit-up holding dumbbells, high pull (rapid lift of weighted bar from floor-to-chest level), and standing bent-arm lateral dumbbell raise. Exercises performed on a Universal Gym apparatus were seated row, standing shoulder shrug, standing military press, and hanging leg raise. Subjects performed 3 to 5 sets of each exercise. If a subject was able to perform a set easily, the weight used was increased for the next set of that exercise. All workouts were preceded and followed by stretching. The control group subjects (n = 7) maintained their preexperiment exercise habits, which did not include progressive resistance training.

Analyses of variance with an alpha of .05 were used to test for group differences in pretraining lifting performance and profiling measures, and pre- to posttraining percent changes. Measures of strength, aerobic power, and anthropometry were correlated with the 10-minute manual materials handling test to determine the relative importance of the various fitness components in performing this type of task.

RESULTS

Increases in strength of the training group confirmed the effectiveness of the progressive resistance training program. The strength determinations and the mean percentage change pre- to posttraining are presented in Table 1. Training group increases in strength were significantly greater than those of the control group for all strength determinations as illustrated in Figure 1. The percentage increases in the training group ranged from 19.8% on the deadlift to 34.6% on the squat.

Measurements made during the manual materials handling test are listed in Table 2. At the end of 12 weeks, the progressive resistance training group increased the number of lifts completed

Table 1. Maximal Weight Lifted by Control (n = 7) and Training (n = 18) Groups Pre- and Posttraining Period

		Pretraining	Posttraining	%Δ
Bench Press	C	79.0 ± 17.4	77.1 ± 14.1	−1.6
	T	76.5 ± 14.5	92.4 ± 16.1	21.3*
Deadlift	C	124.4 ± 23.7	134.0 ± 21.5	8.9
	T	128.9 ± 18.2	153.6 ± 20.2	19.8*
Squat	C	102.5 ± 25.2	111.3 ± 28.5	8.4
	T	104.4 ± 21.7	138.5 ± 21.3	34.6*
Combined†	C	305.9 ± 62.6	322.5 ± 60.5	5.9
	T	309.9 ± 49.7	384.6 ± 52.8	24.7*
Box lift	C	71.9 ± 8.2	79.1 ± 9.3	10.1
	T	73.0 ± 10.3	89.0 ± 10.3	22.8*

* Significantly greater than control group ($p < .05$).
† Combined = bench press + deadlift + squat.
C, control group; T, training group.
Data are given as the mean ± standard deviation and percentage change (%Δ).

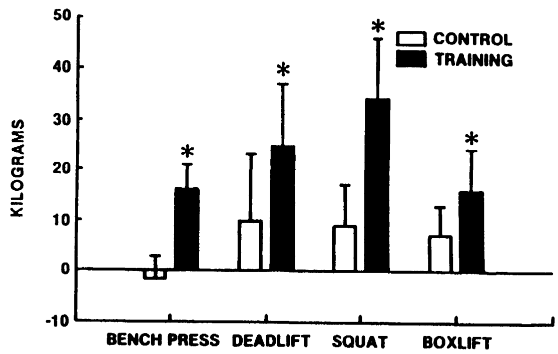

Figure 1. Pre- to Posttraining Period Change in Strength for the Control and Training Groups. * = Significantly Different ($p < .05$) from Control Group.

Table 2. Manual Materials Handling Performance for Control (n = 7) and Training (n = 18) Groups Pre- and Posttraining Period

		Pretraining	Posttraining	%Δ
Lifts completed	C	84.9 ± 26.1	82.0 ± 21.7	−2.4
	T	79.1 ± 17.4	92.4 ± 17.6	18.8*
$\dot{V}O_2$ (ml·kg^{-1}·min^{-1})†	C	41.1 ± 6.5	38.4 ± 7.8	−7.1
	T	37.9 ± 5.0	38.1 ± 7.1	2.0*
Heart rate† (beats·min^{-1})	C	171.0 ± 9.3	169.6 ± 12.1	−4.4
	T	179.1 ± 6.8	182.8 ± 5.8	2.1*
% $\dot{V}O_2$ max†,‡	C	88.9 ± 12.3	86.9 ± 15.0	−2.4
	T	83.1 ± 9.3	88.0 ± 12.1	6.5
Lift height (cm)	C	140.7 ± 3.9		
	T	137.7 ± 5.8		

* Significantly different than control group ($p < .05$).
† Mean for 10 minutes of lifting.
‡ C, control group; T, training group.
Data are given as the mean ± standard deviation and percentage change (%Δ).

during the 10-minute manual materials handling test significantly more than the control group. The mean change in the control group was −2.9 lifts (−2.4%), whereas the training group improved by an average of 13.3 lifts (18.8%).

Pretraining repetitive lifting $\dot{V}O_2$max was 45.6 ± 5.2 ml·kg^{-1}·min^{-1} and 46.5 ± 6.2 ml·kg^{-1}·min^{-1} for the training and control groups, respectively. There was no significant difference between the groups. Because treadmill $\dot{V}O_2$max averages 12% higher than repetitive lifting $\dot{V}O_2$max (Sharp, Harman, Vogel, Knapik, and Legg, 1988), an estimate of the subjects' treadmill $\dot{V}O_2$max would be 51 ml·kg^{-1}·min^{-1}, which is average for males with similar characteristics (Vogel, Patton, Mello, and Daniels, 1986). The progressive resistance training program did not produce an increase in aerobic capacity.

The percentage change from pre- to posttraining in oxygen uptake and heart rate during the manual materials handling test in the training group was significantly different from the control group. When exercise intensity was considered relative to aerobic capacity (%$\dot{V}O_2$max), there was no significant difference between groups pre- or posttraining. For the same relative exercise intensity, the training group was able to complete more lifts after training.

Twelve weeks of progressive resistance training resulted in a greater increase in body mass and fat-free mass in the training group than in the control group, as listed in Table 3. The training group mean increase of 3.7 kg body mass was composed of 2.5 kg fat-free mass and 1.1 kg body fat.

Table 4 contains the correlations between subject descriptive measures and the number of lifts completed in 10 minutes for coinciding measurements made pretraining and posttraining and for the absolute change pre- to posttraining (correlation of post- minus pretraining measurements).

Table 3. Body Composition of Control (n = 7) and Training (n = 18) Groups Pre- and Posttraining Period

		Pretraining	Posttraining	%Δ
Body mass (kg)	C	76.4 ± 12.8	77.0 ± 14.1	0.4
	T	73.3 ± 10.7	77.0 ± 13.1	4.4*
Fat free mass (kg)	C	65.4 ± 10.0	66.3 ± 9.7	1.5
	T	61.9 ± 7.3	64.4 ± 8.1	4.1*
Body fat (%)	C	11.0 ± 5.5	10.7 ± 7.3	−9.4
	T	11.4 ± 5.0	12.5 ± 6.3	6.7

* Significantly greater than control group in percent change ($p < .05$).
C, control group; T, training group.
Data are given as mean ± standard deviation and percentage change (%Δ).

Table 4. Manual Materials Handling Task Performance Pretraining, Posttraining, and Pre-minus Posttraining Periods Correlated with Coinciding Measures of Strength, Aerobic Power, and Body Composition for Twenty-Five Subjects

	Number of Lifts Completed in 10 Minutes		
	Pre-training	**Post-training**	**Pre-Post Δ***
Box lift	0.52†	0.34	0.32
Bench press	0.77†	0.74†	0.61†
Squat	0.56†	0.65†	0.19
Deadlift	0.67†	0.62†	0.57†
Combined‡	0.71†	0.71†	0.53†
Fat-free mass	0.68†	0.64†	0.23
Body mass	0.64†	0.59†	0.24
$\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$)	−0.04	−0.25	0.11

* Posttraining score minus pretraining score.
† ($p < .01$)
‡ Combined, Bench press + deadlift + squat.

Manual materials handling task performance was significantly correlated with all measures of strength before and after training, with the exception of one repetition maximum box lifting strength after training. When pre- to post training change scores were correlated, the change in manual materials handling performance was significantly correlated with the change in bench press, deadlift, and combined strength. Fat-free mass and body mass were significantly correlated with the number of lifts completed in 10 minutes before and after training, but the change in these measures from pre- to posttraining was not significantly correlated. Bench press was most highly correlated with manual materials handling test performance, which suggests that upper-body strength is one of the limiting factors in performing this task. Maximal oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$) was not significantly correlated with manual materials handling task performance at any time, indicating that strength and body size were more important than aerobic power.

DISCUSSION

Progressive resistance training is commonly used to improve athletic performance but has rarely been used to improve occupational task performance. Most studies of occupational training have involved task-specific training. In two previous studies, task-specific training programs resulted in a 26% increase in load lifted for a 1 hour repetitive lifting task (Sharp and Legg, 1988), and 248% increase in endurance time on a symmetrical lifting task (Genaidy, Bafna, Sarmidy, and Sana, 1990). In the present investigation, the improvement in manual materials handling performance resulting from progressive resistance training (18.8%) is more modest than that reported for task-specific training. It is important to recognize, however, that task-specific training is not a reasonable option for many occupations, due to the cost of training and the risk of injury. Progressive resistance training provides a convenient, economical, and safe alternative to task-specific training. Repeated-task performance (task-specific training) maintains, but does not improve, job performance after an initial period of gain. Progressive resistance training can be performed on an individually determined schedule, with steadily increasing loads to yield improvement in task performance.

The progressive resistance training group showed a significantly greater increase than the control group in all measures of strength. The increases were similar to those observed in other progressive resistance training studies of similar duration and frequency (Fleck and Kraemer, 1987, Atha, 1981). Greater training group increases were not unexpected for those measures employed as exercises within the progressive resistance training program (bench press, deadlift, and squat). However, there was also a significantly greater increase in occupational lifting strength (23%) in the training group than in the control group (10%), as measured by a single lift of a maximally loaded box. That box lifting was not utilized as a training exercise in the present study demonstrates the effectiveness of a program designed to strengthen the muscles important to a particular activity. The deadlift exercise was similar in technique to the initial portion of the box lift (floor-to-knuckle height), and the high pull and bench press exercises simulated the second portion of the lift (knuckle-to-shoulder height and push onto the shelf).

Sharp and Legg (1988) observed a 6% increase in maximal box lifting strength following repetitive box lifting with no progressive increase in load lifted, whereas Asfour and coworkers (1984) found a 55% increase in box lifting strength with progressive resistance box lifting training. The 55% increase was double that observed in the present study and may be due to the use of the same movement for testing and training. It may also be due to a subject sample with a lower initial level of strength. The subjects in the current study had a pretraining maximum box lift score that was 20 kg greater than the pretraining measurement reported by Asfour et al. (1984). As an individual approaches his genetic potential for developing strength, the rate at which strength gains are achieved is reduced (Fleck and Kraemer, 1987). This is supported by the work of Genaidy (1991) who found little improvement with training in the box lifting strength in a group of subjects whose initial lifting strength was 90.6 kg. A 20% improvement was found in a group of subjects with a 32.3-kg maximum box lift. Lifting progressively heavier boxes is the most effective way to improve box lifting strength, but not all occupational tasks requiring physical strength lend themselves to task-specific strength training.

Progressive resistance training provides the opportunity for maximal increases in strength. By increasing strength to levels beyond that required by the job, workers can reduce the job stress ratio, which is the ratio of load lifted to the workers maximum lifting strength. Stronger employees and lower job stress ratios are associated with fewer injuries (Cady, Thomas, and Karwasky, 1985; Chaffin, 1974; Marcinik, 1986).

Progressive resistance training is an attractive alternative for work hardening programs. Patients from different occupations can be treated with individualized programs using the same facilities and equipment. Purchase of expensive weight training machines is unnecessary, because a small investment in a full set of free weights and dumbbells should meet the needs of most individuals. Fabricated exercise equipment, such as sandbags, has also been successfully utilized in a progressive resistance training program (McMurray, Harrell, and Griggs, 1990). A thorough evaluation of the job requirements must be made to select the appropriate training exercises and equipment to produce the desired increase in job performance.

This study has demonstrated that progressive resistance training can increase both the rate of manual materials handling with a heavy load and the amount of weight lifted in a single maximal effort. Progressive resistance training programs should be particularly useful in physically demanding jobs where it is not practical to train by performing the specific occupational tasks.

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