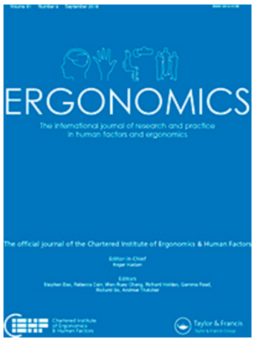

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Maximum weights of lift acceptable to male and female industrial workers for extended work shifts

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This paper reports the development of maximum acceptable weight of lift databases for male and female industrial workers for 12-hour work periods. Using a psychophysical methodology, 37 males and 37 females, experienced in manual lifting, performed various lifting tasks involving four frequencies, three box sizes, and three height levels. The maximum acceptable weight of lift was significantly influenced by the frequency of lift, height of lift, and box size. Box size effects were, however, less profound than frequency, and height effects. The maximum weight, acceptable for 12 hours of lifting, elicited an average heart rate of 90 and 101 beats min^{-1} for males and females, respectively. Males selected weights that, on average, resulted in metabolic energy expenditure rates of 23% of their aerobic capacity for 12 hours of lifting. Females required metabolic energy expenditure rates equivalent to 24% of their aerobic capacity for lifting acceptable levels of weight for 12 hours.

1. Introduction

It is now well established by the National Institute for Occupational Safety and Health (NIOSH 1981) that the majority of material handling related over-exertion injuries in industry are caused by manual lifting. In the United States, approximately 35% of all compensation claims are related to back injuries (National Safety Council 1983) and an estimated 14 billion dollars are paid annually in direct financial compensation (Taber 1982). The indirect costs may be as much as four times this amount (Asfour *et al.* 1983). A reduction in the number, severity and the resulting costs of these injuries has been of serious concern to many researchers and health related agencies. Their combined efforts have led to the publication of a work practice guide for manual lifting by NIOSH (1981).

Two different approaches have emerged over the years to reduce the number and severity of industrial over-exertion injuries caused by manual lifting. These suggest that either jobs be designed to match human capabilities or that people be screened to match job demands with individual capacities. For job design, data describing the material handling capabilities of various population groups have been reported by Chaffin *et al.* (1977 a), Snook (1978), Mital *et al.* (1978), Ayoub *et al.* (1980), and Mital and Asfour (1983), and others. To match the worker and task, elaborate models have been developed to predict the lifting capability of an individual or a given population percentile (Garg 1976, Chaffin *et al.* 1977 b, Mital and Ayoub 1980, 1981, Mital 1983 a and b).

In all previous investigations 8-hour work shifts have been assumed. However, longer work shifts are common in the industrial environment, though no data or models, based on an extended work shift (more than 8 hours per day), are available in the literature. NIOSH lifting guidelines (1981) indicate that over-exertion injuries associated with manual lifting activities have not decreased in the last decade. Increased shift duration (10 or 12 hours) is expected to increase this injury hazard due to chronic build up of fatigue over a longer period of time each working day.

The underlying assumption of the research conducted to date in this area has been that the working population will operate for only 8-hours every day. This assumption is still valid in a majority of industries. However, situations where workers are asked to put in an extra 2 or 4 hours of work are not uncommon. Many industries have a 10-hour or 12-hour working shift on a regular basis. The workers in these situations, when the shift is formally extended, generally do not work five days a week, but in cases where this extension is in the form of overtime, five working days a week are common. Several manufacturing industries in the mid-western United States follow this pattern.

In order to develop comprehensive guidelines for manual lifting, and other manual handling activities, it is important that the effect of time duration on the job be taken into consideration. Longer work duration (more than 8 hours/day) means lower rates of metabolic energy expenditure (below the widely accepted 20·93 kJ min^{-1} energy expenditure rate) if the physiological fatigue is to be avoided (Mital 1983 c). Also, as noted above, prolonged workshifts may also increase hazard potential, though, at present there is no evidence to support the hypothesis that longer shifts lead to higher injury rates. However, reduced metabolic demands to avoid fatigue (Mital 1983 c) may support such a hypothesis.

The purpose of this research project, supported by the National Institute for Occupational Safety and Health (NIOSH), was (i) to obtain data for manual lifting activities based on extended work shift (12 hours per day) and (ii) to integrate data from the present study with that of Snook (1978) and Ayoub *et al.* (1978). This paper addresses the first of these objectives and considers the maximum acceptable weights of lift data for extended work-shifts. A further paper deals with comprehensive maximum acceptable weight of lift data, for regular 8-hour work-shifts, based on this study and studies of Snook (1978) and Ayoub *et al.* (1978).

2. Method

2.1. *Subjects*

Industrial workers, 37 male and 37 female, all experienced in lifting goods manually for 12 hours each working day, were recruited to participate in the study. A personal data form was used to screen out those subjects who were relatively inexperienced in manual lifting (less than 6 months), had a history of back injury, were on medication, or had some other physical ailment. Successful candidates, after this preliminary screening, were questioned orally about their work and experience to determine further their suitability for participation in the experiment. Once it was ascertained that the subject was in good health and had experience in manual lifting, he or she was allowed to participate in the experiment.

Anthropometric and isometric strength measurements were made on the subjects prior to the experiment. Measurements recorded included age, body weight, stature, arm strength, shoulder strength, etc. Isometric strengths were measured in accordance with the procedures outlined by Caldwell (1974) and Chaffin (1975). The mean, standard deviation, and range of these measurements are tabulated in table 1.

2.2. *Experimental design*

A balanced incomplete randomized block factorial design was used. Four lifting frequencies (1, 4, 8, and 12 lifts per min), three height levels (floor to knuckle, knuckle to shoulder, and shoulder to reach), and three box sizes (30·48, 45·72, and 60·96 cm long in the sagittal plane) were used as the levels of the independent variables. The incomplete block design was selected due to its simplicity. Significant time and practical difficulties

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

	Males			Females		
Variable	Mean	S.D.	Range	Mean	S.D.	Range
Age (years)	34·05	10·42	88–61	35·46	9·84	21–58
Stature	172·79	6·60	155·70–186·80	164·70	6·18	154·10–176·70
Body weight (kg)	81·18	16·66	53·57–121·70	69·68	13·78	44·13–110·80
Shoulder height	143·52	6·42	128·20–157·00	135·42	5·85	127·20–149·10
Illiac Crest height	99·23	4·55	89·10–107·90	97·13	5·59	85·00–107·80
Knuckle height	77·63	4·33	69·00–86·30	72·93	4·04	65·30–81·90
Knee height	50·08	3·02	43·60–56·10	46·64	3·22	40·20–54·00
Forearm grip distance	36·82	2·23	32·50–41·80	34·61	2·08	29·80–38·50
Chest width	32·43	3·87	22·30–41·50	29·90	2·59	25·30–35·70
Chest depth	22·02	3·35	13·10–28·80	18·96	1·92	16·20–23·70
Abdominal depth	22·10	4·27	13·40–34·60	19·96	3·84	15·40–31·00
Arm strength	34·73	10·47	14·00–61·00	19·03	5·74	9·00–35·00
Shoulder strength	44·46	14·48	23·00–101·00	22·05	6·85	11·00–38·00
Composite strength	99·35	27·98	55·00–169·00	54·49	16·44	28·00–102·00
Back strength	55·30	19·71	21·00–116·00	36·00	10·40	20·00–73·00

* Body measurements are in centimetres; strength measurements are in kilograms.

are otherwise involved, if each subject performs all the 36 treatment combinations (4 frequencies × 3 height levels × 3 box sizes); each treatment combination lasting approximately 45 min. For instance, it was not possible for most of the subjects to return and complete the experiment on the second and subsequent days. The majority of the subjects could participate only for one day. A design involving 37 subjects, 37 treatments, and 37 blocks was, therefore, chosen (Cochran and Cox 1957). In order to remove differences among subjects, they were treated as blocks.

Since the design selected involved 37 treatments and only 36 treatments were possible, one of the treatment combinations was randomly selected and repeated as treatment number 37. Subjects were stratified across ages by dividing them into three groups (group 1—up to 29 years of age; group 2—from 30 to 39 years of age; group 3—above 39 years of age). There were 12 male and 12 female subjects in groups 1 and 3; group 2 had 13 males and 13 females. This stratification permitted the subject population to be representative of the industrial population across a wide age range.

To contain the size of the experiment and allow comparison with specific past studies, several variables were controlled. The room temperature was maintained at 21–22°C; the relative humidity was 45–55%. Boxes were fitted with handles (12·7 × 7·6 cm—located 12·7 cm above the base of the box) and were 15·24 cm high and 30·48 cm wide (dimension in the frontal plane). Lifting was performed using a free-style technique. No external motivation was provided.

The maximum acceptable weight of lift, the heart rate and the metabolic energy expenditure rate of the individual were the response variables. Heart rates and metabolic energy expenditure rates were measured at the maximum acceptable weight of lift, after the steady state was reached.

2.3. *Experimental procedure*

A modified psychophysical approach was used by the subjects to determine the maximum acceptable weight of lift and the experimental procedure was the same for each subject. Following the strength and anthropometric measurements, the subject was instructed in the lifting procedure, and depending on the design chosen, each subject was required to perform nine treatment combinations (out of a possible 36). Under each treatment combination, subjects were required to lift weight in a specified size box, using the handles, from one given height to another, at a given frequency determined by a metronome. The subjects started with either a light or heavy load (lead shot and lead pieces) in the box and were then allowed to make adjustments by adding or removing weight from the box (psychophysical approach). They were asked to assume an 8-hour long work shift (including meal and rest breaks) and make as many adjustments as necessary to arrive at the maximum weight that they felt they could comfortably lift, without feeling tired or exhausted. This process took approximately 20–25 min to complete after which this maximum acceptable weight of lift was measured. The oxygen uptake and heart rate of the subject, at this maximum acceptable weight of lift for an 8-hour period, were also measured. The physiological data were recorded for three full minutes and only after the steady state was reached. An MRM-1 oxygen computer and a Quinton heart rate meter were used for this purpose. The subject was then asked to assume an extra 4-hour work period (4 hours of overtime having just completed an 8-hour shift; no rest allowances were provided in-between) and resume the lifting activity. During this phase, the subject was permitted to make further adjustments to the weight in the box. This phase also lasted approximately 20–25 min, at the end of which, the maximum acceptable weight of lift, the oxygen uptake, and the heart rate were again measured. This new weight was for a full 12 hours. There were two reasons for using this procedure: (i) to obtain additional data for 8-hour shifts and (ii) frequently workers are asked to put in four extra hours of work at the end of the 8-hour shift. It was considered that if the new weight was lower than the earlier weight estimate, it would be primarily due to the extended shift duration and the 40–45 min work period would allow individuals to determine the weight they would like to lift for 12 hours even if it included four hours of overtime about which they had no prior warning.

The above procedure was repeated for all planned treatment combinations for each subject. Treatments were performed in a random order. No rest allowance was provided between the treatments except the time necessary to change the equipment settings for the next treatment combination.

2.4. *Data adjustments*

The psychophysical approach used in this study and many past studies was validated earlier by the author, on industrial subjects, in an independent study (Mital 1983 c). The study revealed that individuals cannot continue to accept lifting the same amount of weight, estimated earlier based on a trial period of 20–45 min while assuming either an 8-hour or 12-hour work period, for 8 hours or 12 hours, respectively. The rates of decrease with time, assuming the initial psychophysical estimate for 8 hours to be 100%, were estimated to be approximately 3·4% per hour for males and 2% per hour for females. The heart rate decreased by about 1·9% per hour for males and 0·8% per hour for females. As the maximum acceptable weight of lift decreased, so did the metabolic cost of lifting it. The decline in metabolic energy expenditure was approximately 2·6% per hour for males and 1·9% per hour for females.

All the data collected in the study reported here were adjusted by the multipliers given above. As mentioned by Mital (1983 c), such adjustments are essential if the psychophysical methodology is used to determine how much weight people are willing to lift. Failure to adjust the data, collected after only 20–45 min of lifting, would result in over estimating weights that people are willing to lift. Such over estimation of an individual's lifting capability or acceptable weight of lift is expected, therefore, to increase his or her personal risk for injuries due to increased build up of fatigue.

3. Results

3.1. *Maximum acceptable weight of lift*

The estimated maximum weight, acceptable to males for the simulated 12-hour shift, was significantly lower than the estimated weight acceptable to them for the simulated 8-hour shift ($p<0{\cdot}01$). For females, there was no difference in the two estimates ($p>0{\cdot}10$). As indicated earlier, the maximum acceptable weight of lift decreased by 3·4% per hour for males and 2% per hour for females. These multipliers were used to adjust the psychophysical estimate of the maximum acceptable weight of lift for 8 hours to obtain lifting capability data for 12 hours.

The means and standard deviations of maximum acceptable weights of lift for 12 hours, based on data collected on 37 males and 37 females, are tabulated in tables 2 and 3. Table 2 shows data for males and table 3 for females. In addition to the weight of lift data, heart rate and oxygen consumption values are also shown. The overall values of the response variables (weight, heart rate, oxygen consumption) for all task variables are tabulated in table 4 for both males and females.

Males lifted significantly more weight for 12-hour shift than females ($p<0{\cdot}01$). To determine the levels of maximum weight of lift acceptable to male and female industrial workers for time duration between 8 and 12 hours, interpolation between the values given in tables 2 and 3 and the comprehensive data for 8 hours given in the following paper may be used. For obtaining maximum acceptable weight of lift values when lifting duration is less than 8 hours, extrapolation is suggested.

The average heart rate of males and females, for 12 hour lifting duration, were 90 and 101 beats min^{-1}, respectively. The average metabolic energy expenditure rate of males was 12·56 kJ min^{-1} at the acceptable level of weight selected for 12 hours. The corresponding metabolic energy expenditure rate value for females was 8·37 kJ min^{-1}. These average metabolic energy expenditure rates of males and females, at the weights acceptable for 12 hours of lifting, correspond to approximately 23 and 24% of their aerobic capacity, respectively (the aerobic capacities were estimated from Chaffin (1972)).

3.2. *Box-size effect*

The decrement (%) in the maximum acceptable weight of lift due to box size (box dimension in the sagittal plane) is given in table 5. In general, the influence of box size was not very large. The maximum weight of lift, acceptable to males, decreased significantly ($p<0{\cdot}05$) as the box size increased from 30·48 to 45·72 cm (by 6%). The further decrease (2%) in the maximum acceptable weight of lift, as the box size increased from 45·72 cm to 60·96 cm, however, was not significant ($p\geqslant0{\cdot}10$). For females, the initial decrease in the maximum acceptable weight of lift (2%), when the box size increased from 30·48 to 45·72 cm, was not statistically significant ($p\geqslant0{\cdot}10$). There was also no significant difference in the maximum weights females lifted in the 45·72 and 60·96 cm boxes ($p\geqslant0{\cdot}10$). Females, however, lifted significantly more weight (5% more) in the 30·48 cm box compared to the 60·96 cm box ($p<0{\cdot}01$). Males also lifted significantly more weight (8%) in the 30·48 cm box compared to the 60·96 cm box ($p<0{\cdot}01$). The means and standard deviations of actual weights lifted are shown in

Table 2. Maximum weight of lift acceptable to male industrial workers for twelve hours and their physiological responses at that weight.

			Frequency of lift (lifts per minute) 1			4			8			12		
	Box size (cm)		30·48	45·72	60·96	30·48	45·72	60·96	30·48	45·72	60·96	30·48	45·72	60·96
Floor to knuckle height	Weight (kg)	$\bar{X}$	13·33	12·02	13·05	12·20	10·56	10·66	11·89	9·39	8·59	8·19	7·54	7·34
		S	3·63	2·92	2·70	3·87	2·77	3·12	4·66	1·79	1·71	2·93	2·53	1·84
	Heart rate	$\bar{X}$	81·44	72·82	74·19	88·03	88·69	92·64	102·91	101·24	100·65	100·88	109·90	107·36
	(beats min^{-1})	S	13·29	10·34	13·24	15·27	8·38	18·64	18·60	14·03	18·55	14·87	17·10	11·55
	Oxygen uptake	$\bar{X}$	0·40	0·34	0·40	0·69	0·73	0·68	0·85	0·86	0·91	0·99	0·87	0·88
	(l. min^{-1})	S	0·21	0·15	0·20	0·19	0·25	0·20	0·23	0·20	0·16	0·23	0·24	0·19
Knuckle to shoulder height	Weight	$\bar{X}$	12·44	12·82	11·88	10·51	11·67	10·69	9·90	9·48	8·40	8·69	9·10	7·93
		S	3·28	3·75	3·26	2·35	2·19	3·37	2·04	2·34	2·25	2·18	2·69	1·95
	Heart rate	$\bar{X}$	83·33	80·79	78·12	95·88	94·61	89·72	98·51	91·11	91·00	97·52	106·54	98·10
		S	14·13	12·02	11·60	14·87	13·44	15·68	13·75	9·79	16·78	14·91	12·96	12·40
	Oxygen uptake	$\bar{X}$	0·27	0·38	0·39	0·51	0·57	0·59	0·63	0·72	0·65	0·75	0·75	0·58
		S	0·13	0·20	0·11	0·18	0·19	0·23	0·19	0·25	0·16	0·19	0·21	0·12
Shoulder to reach height	Weight	$\bar{X}$	10·11	9·58	10·86	9·69	10·05	9·36	8·95	9·23	9·80	8·85	7·70	7·87
		S	2·75	1·76	3·10	3·40	3·57	1·80	2·44	1·63	3·59	2·24	1·72	1·78
	Heart rate	$\bar{X}$	69·50	76·09	72·18	81·63	84·99	83·30	90·39	88·82	96·74	94·77	85·67	89·55
		S	11·27	8·45	15·15	12·31	13·37	16·64	11·00	10·09	16·81	20·61	10·98	13·58
	Oxygen uptake	$\bar{X}$	0·30	0·30	0·31	0·46	0·52	0·52	0·54	0·53	0·70	0·68	0·62	0·68
		S	0·15	0·14	0·16	0·23	0·17	0·18	0·18	0·20	0·28	0·18	0·20	0·21

Note: $\bar{X}$ = Mean; S = Standard deviation.

Table 3. Maximum weight of lift acceptable to female industrial workers for twelve hours and their physiological responses at that weight.

			Frequency of lift (lifts per minute)											
			1			4			8			12		
	Box size (cm)		30·48	45·72	60·96	30·48	45·72	60·69	30·48	45·72	60·96	30·48	45·72	60·96
Floor to knuckle height	Weight (kg)	$\bar{X}$	11·90	11·71	10·18	10·32	9·46	10·17	8·87	7·55	7·53	7·42	8·37	8·17
		S	2·27	2·38	2·06	2·73	2·37	2·67	2·44	2·10	1·00	2·16	2·64	2·47
	Heart rate	$\bar{X}$	89·08	92·46	87·18	103·15	99·60	97·54	108·61	111·09	98·16	116·44	121·78	113·51
	beats min^{-1}	S	7·22	10·11	9·92	15·02	17·13	14·07	19·08	8·01	10·18	17·67	14·86	12·43
	Oxygen uptake	$\bar{X}$	0·36	0·30	0·36	0·52	0·44	0·55	0·64	0·54	0·50	0·57	0·66	0·56
	(l. mun^{-1})	S	0·17	0·15	0·17	0·13	0·20	0·27	0·37	0·13	0·16	0·17	0·22	0·20
Knuckle to shoulder height	Weight	$\bar{X}$	10·06	10·58	9·41	9·07	9·32	8·91	8·15	7·86	7·93	6·93	7·91	7·50
		S	1·97	2·47	2·18	1·64	2·17	2·29	1·58	1·30	2·11	0·89	1·67	2·00
	Heart rate	$\bar{X}$	90·89	89·07	88·27	98·57	98·33	103·52	107·57	100·41	102·08	114·70	120·51	102·73
		S	12·11	9·45	13·25	9·76	10·95	12·98	12·64	8·67	14·65	12·43	13·79	16·54
	Oxygen uptake	$\bar{X}$	0·25	0·26	0·16	0·34	0·34	0·37	0·43	0·45	0·45	0·45	0·59	0·47
		S	0·13	0·15	0·05	0·18	0·21	0·24	0·13	0·07	0·22	0·15	0·17	0·15
Shoulder to reach height	Weight	$\bar{X}$	9·38	7·92	7·66	8·57	7·98	8·03	7·93	7·93	7·57	7·33	6·46	7·15
		S	1·89	1·34	0·96	1·94	1·39	1·68	1·03	1·66	1·50	0·93	0·91	1·04
	Heart rate	$\bar{X}$	86·80	86·65	83·07	97·58	93·58	84·12	106·20	94·96	105·83	102·44	110·27	109·67
		S	8·91	9·10	6·66	11·87	14·03	13·04	12·85	11·57	14·58	15·11	10·13	18·52
	Oxygen uptake	$\bar{X}$	0·15	0·24	0·18	0·35	0·28	0·23	0·49	0·30	0·47	0·31	0·39	0·46
		S	0·69	0·18	0·09	0·12	0·17	0·08	0·27	0·20	0·23	0·10	0·18	0·19

Note: $\bar{X}$ = Mean; S = Standard deviation.

Table 4. Overall means and standard deviations of responses for independent variables.

Variable	Response	Males $\bar{X}$	Males S	Females $\bar{X}$	Females S
Box size (cm)					
30·48	Weight (kg)	10·57	3·44	8·78	2·21
	Heart rate (beats min^{-1})	90·07	16·85	102·22	15·45
	Oxygen uptake (l. min^{-1})	0·59	0·27	0·40	0·21
45·72	Weight	9·91	2·87	8·59	2·31
	Heart rate	90·27	15·77	101·74	16·00
	Oxygen uptake	0·60	0·27	0·40	0·21
60·96	Weight	9·69	3·01	8·35	2·08
	Heart rate	89·48	17·78	97·97	16·02
	Oxygen uptake	0·61	0·25	0·40	0·22
Frequency (lifts/min)					
1	Weight	11·80	3·18	9·87	2·36
	Heart rate	76·60	12·55	88·16	9·68
	Oxygen uptake	0·34	0·16	0·25	0·15
4	Weight	10·76	3·12	9·09	2·18
	Heart rate	88·75	14·66	97·33	13·82
	Oxygen uptake	0·60	0·21	0·38	0·20
8	Weight	9·50	2·72	7·94	1·64
	Heart rate	95·62	14·95	104·20	13·11
	Oxygen uptake	0·71	0·24	0·47	0·21
12	Weight	8·14	2·21	7·48	1·79
	Heart rate	98·92	15·89	112·56	15·55
	Oxygen uptake	0·76	0·23	0·50	0·20
Height of lift					
Floor to knuckle	Weight	10·55	3·58	9·30	2·67
	Heart rate	93·06	18·27	103·34	16·72
	Oxygen uptake	0·71	0·28	0·50	0·22
Knuckle to shoulder	Weight	10·28	3·01	8·60	2·06
	Heart rate	92·03	15·17	101·86	14·98
	Oxygen uptake	0·57	0·23	0·38	0·19
Shoulder to reach	Weight	9·34	2·60	7·83	1·50
	Heart rate	84·47	15·37	96·76	15·36
	Oxygen uptake	0·51	0·23	0·32	0·19

Note: $\bar{X}$ = Mean; S = Standard deviation.

table 4. For both males and females, the heart rate and oxygen uptake were not influenced by changes in box size ($p \geqslant 0{\cdot}10$).

3.3. *Frequency effect*

The maximum acceptable weights lifted at different frequencies, expressed as percent of weight lifted at one lift per minute, are tabulated in table 5. As the frequency of lift increased, the maximum acceptable weight of lift decreased. The amounts of weight acceptable for lifting at various frequencies were significantly different from each other ($p < 0{\cdot}01$) both for males and females. The maximum weight of lift acceptable to males at 12 lifts per minute was 69% of the maximum weight acceptable to them at one lift per minute. For females, the corresponding figure was 76%. In general, the effect of frequency was more marked in males than females.

Table 5. Decrement (%) in maximum acceptable weight of lift with frequency, box-size and height of lift.

Variable	Males	Females
Box size (cm)		
30·48	100*	100
45·72	94	98
60·96	92	95
Frequency (lifts/min)		
1	100	100
4	91	92
8	81	80
12	69	76
Height of lift		
Floor to knuckle	100	100
Knuckle to shoulder	97	92
Shoulder to reach	89	84

* Numbers rounded to the nearest integer.

The physiological responses, heart rate and oxygen uptake, increased with the frequency of lift. For both males and females, corresponding values of heart rates and oxygen uptakes, at various lifting frequencies, were significantly different from each other ($p<0{\cdot}01$). Females had significantly higher average heart rate values compared to males ($p<0{\cdot}01$). The trend observed for heart rate was reversed for oxygen uptake. Increases in oxygen uptakes were significantly lower for females than for males ($p<0{\cdot}01$). The average value of heart rate for males increased from approximately 77 beats min^{-1}, at one lift per minute, to 100 beats min^{-1}, at 12 lifts per minute. The average heart rate for females increased from approximately 88 beats min^{-1}, at one lift per minute, to 113 beats min^{-1}, at 12 lifts per minute.

3.4. *Height level effect*

Three different height levels were included in this study. The amounts of weight lifted by males and females at different height levels were expressed as percent of weight lifted at the floor to knuckle to height level and are tabulated in table 5. The amount of weight accepted for lifting decreased as the starting point of lift changed from the floor level to the shoulder height level. This pattern was consistent for both males and females. For males, the maximum acceptable weight of lift decreased from 100%, at the floor to knuckle height level, to 89%, at the shoulder to reach height level. For females, the corresponding decrease was from 100 to 84%. The decrease in acceptable weight of lift was more profound for females than males (11% versus 16% from the floor to knuckle height to shoulder to reach height). Also, for approximately the same vertical distance (0·51 m), the acceptable weight of lift was 8% lower, for either males or females, when the starting point of lift changed from the knuckle height to the shoulder height. For both males and females the amount of weight lifted at various height levels were significantly different from each other ($p<0{\cdot}01$).

Significantly more oxygen was consumed at tne floor to knuckle height level than at any other height level ($p<0{\cdot}01$). The amount of oxygen consumed also decreased significantly ($p<0{\cdot}01$) when the starting height changed from the knuckle height to the shoulder height. Heart rate of individuals also decreased with the starting point height.

With the exception of heart rates at the floor to knuckle height level and knuckle to shoulder height level, for males, all other heart rates were significantly different from each other ($p < 0.01$).

4. Discussion

This paper reports 'the maximum acceptable weight of lift' databases for 12-hour shifts for the industrial male and female population. The data are presented as a function of lifting frequency, box size, and height of lift.

In general, males were willing to lift more weight than females. This weight, acceptable to males and females, resulted in metabolic energy expenditure rates which were approximately 23 and 24% of their aerobic capacity, respectively (Mital 1983 c). It appears that these low metabolic energy expenditure rates are due to lower weights handled. Workers could no sustain one-third of their aerobic capacity for 12 hours. The data suggests that the fraction of the aerobic capacity that can be sustained for 12 hours should be around one-fourth.

As expected, the maximum acceptable weight of lift decreased with the box-size (dimension in the sagittal plane). Since bigger boxes, for the same load, exert a larger bending moment on the spinal column, subjects responded by accepting lighter loads. The maximum acceptable weight of lift also decreased with frequency. This was expected. With every lift, individuals also lift a part of their body. In some cases, the weight of body parts lifted may be as much as 60% of the individual's body weight (Ayoub *et al.* 1978). Since at higher frequencies, fatigue build up is greater, subjects compensate for that by accepting lower weights which is the only adjustable variable.

Both, males and females, accepted higher weights for the floor to knuckle height level even though it produces greater truncal stress and results in more oxygen consumption and higher heart rates. It appears that since workers can rely more on their thigh and back muscles for low level lifts, more weight is lifted. Elevated heart rate and oxygen uptake are probably due to the larger mass of muscles involved. At higher level lifts, however, arm muscles mainly come into play causing lower acceptable weights, heart rates, and oxygen uptake.

The maximum acceptable weight of lift was also not influenced by the age of subject. No significant differences were found among the three age groups either for males or females ($p > 0.10$). This was consistent with the findings reported by Mital *et al.* (1978) and Ayoub *et al.* (1978). Apparently experience on the job compensates for any physiological changes due to aging.

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Dans cet article, on rend compte de l'élaboration d'une base de données relative aux charges acceptables pour le soulèvement pour des ouvriers, hommes et femmes, au cours de périodes de travail de 12 heures. On a fait appel à une technique psychophysique et on a examiné trente-sept hommes et trente-sept femmes qui devaient effectuer diverses tâches de soulèvement, avec quatre fréquences, trois tailles de caisse et trois hauteurs de niveau différents. La charge maximale acceptable était significativement affectée par la fréquence du soulèvement, par la hauteur et par la taille de la charge. La charge maximale acceptable pour un soulèvement de 12 heures, produisait une fréquence cardiaque moyenne de 90 et de 101 battements par minute, respectivement pour les hommes et les femmes. Les hommes sélectionnaient des charges qui, en moyenne, entrainaîent une dépense d'énergie métabolique de 23% de leur capacité aérobique pour 12 heures de soulèvement. Les femmes requéraient 24% dans les mêmes conditions.

In dieser Veröffentlichung wird über die Ermittlung von Grundlagendaten der maximal zulässigen Gewichte für Umsetzen von Lasten durch Männer und Frauen bei zwölfstündiger Arbeitsdauer berichtet. Unter Verwendung der psychophysikalischen Methodik haben jeweils siebenunddreißig im Heben von Lasten erfahrene Männer und Frauen unterschiedliche Aufgaben der Lastenumsetzung ausgeführt, die vier Umsetzfrequenzen, drei Behältergrößen und drei Höhenstufen einschloßen. Das maximal zulässige Gewicht beim Umsetzen wurde signifikant von der Umsetzfrequenz, Hubhöhe und Behältergröße beeinflußt. Die Auswirkung der Behältergröße wurden jedoch weniger ausgeprägt als diejenigen der Umsetzfrequenz und der Höhenstufen. Das maximale zulässige Gewicht für zwölfstündige Arbeitsdauer führte zu einer durchschnittlichen Herzschlagfrequenz von 90 bzw. 101 Pulse/min bei Männern und Frauen. Männer haben im Durchschnitt Gewichte ausgesucht, die zu einem Energieumsatz von 23% ihrer aerobischen Kapazität für zwölfstündige Lastenumsetzung führten. Bei Frauen ergab sich für zulässige Gewichte bei zwölfstündigem Umsetzen ein Energieumsatz von 24% ihrer aerobischen Kapazität.

本論文は12時間勤務労働者男女の最大許容持上げ重量のデータベースの開発を報告するものである。精神物理的な方法を用い，手による持上げ作業に熟練した男性37名と女性37名に，様々の条件の持上げ作業を行わせた。持上げ条件は，持上げ頻度を 4 段階，箱の大きさを 3 種，持上げ高さを 3 段階に変化させた。最大許容持上げ重量は，持上げ頻度，持上げの高さ，および箱の寸法によって有意な変化を示したが，箱の寸法の影響が最も少なかった。12時間の持上げ作業に対する最大許容重量時の心拍数の平均値は男性で90bpm、女性で101bpmであった。12時間の持上げ作業に対して，男性は酸素容量の23%に等しい代謝エネルギー消費率となる重量を選択し，女性は24%に等しい代謝エネルギー消費率の重量を選んだ。

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