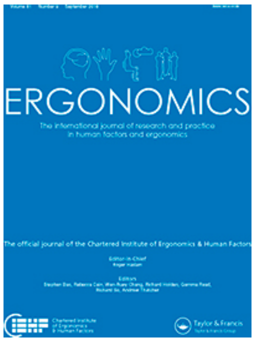

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Handle positions in a holding task as a function of task height

By J. M. DEEB, C. G. DRURY and K. L. BEGBIE

Department of Industrial Engineering, State University of New York at Buffalo, 342 Bell Hall, Buffalo, New York 14260, U.S.A.

Six handle positions in a two-handed container holding task were tested with the container at floor, waist and shoulder heights. Fifteen male and fifteen female manual materials handlers participated. Handle-position effects on forces exerted, heart rate and psychophysical indices were large compared with the effect produced by a 25% change in container weight. As in a previous study (at waist height only) and an industrial survey, handle positions providing both horizontal and vertical stability were better than symmetrical positions. Optimal angles of handle to container changed greatly with task height, giving almost horizontal angles at floor level and almost vertical angles at waist and shoulder level. Implications for the design of handle cutouts on containers are discussed.

1. Introduction

It is generally agreed among ergonomists that the best long-term approach to reducing manual-materials-handling (MMH) injuries is to redesign the task and the container to fit the operator (see, for example, Snook 1978). In many industrial operations the same container is used repeatedly, e.g. in packing, shipping, warehousing, receiving and unpacking. Thus, appropriate container design should help eliminate injuries in many tasks (including such unexpected tasks as retrieving fallen containers).

The spinal stresses of manual materials handling are affected by the size and shape of the container (Tichauer 1971), but there is more to container design than size and shape. The container should be as compact as possible, particularly in the length dimension, to reduce the moment about the lower back. The manner in which the worker holds the container has a marked effect on the stresses in other parts of the body. This 'coupling' between the body and the container has been shown to influence the stress on the worker. W. J. Nielson (1978, personal communication) showed that handles can increase the forces exertable on a container by up to 20%. Garg and Saxena (1980) tested a range of box sizes using a psychophysical methodology and found increases in maximum acceptable container weight from just over 1 kg (4·0%) to more than 3 kg (11·5%) with the addition of handles. Even stronger evidence of handle effectiveness comes from experiments performed at SUNY of Buffalo (Coury and Drury 1982, Drury *et al.* 1982).

In the laboratory study of Coury and Drury (1982) subjects held boxes using different pairs of hand positions while biomechanical, physiological and psychophysical measures were taken. Ten male subjects each performed 100 trials of a static holding task with a box held at waist height using all possible combinations of hand positions 3, 6, 8 and 9 from figure 1.

Handles were freely pivoting so that the handle could assume a natural angle with respect to hand, wrist and arm. Handle angles (upper and lower) were measured for each trial. The handle forces were measured, and the reaction and friction forces at the

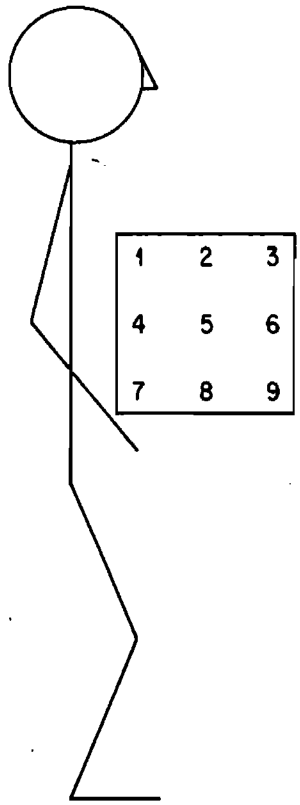

Figure 1. Handle position labels (after Drury *et al.* 1982).

torso/box interface calculated. Heart rate during the task, rated perceived exertion (Borg 1962), and body part discomfort (Corlett and Bishop 1976) were evaluated in each trial.

Handle position had a large effect on all measures. Asymmetric handle positions (e.g. 3/8 or 6/8) gave the minimum physiological and perceived stress, while symmetric balanced positions (e.g. 8/8) minimized forces exerted on the handles by the hands. In the asymmetric positions, the box/body interface was used to a considerable extent. The handles were being used to help the worker hold the container against his body and so relieve the hands and arms of upward lifting forces at the expense of horizontal 'hugging' forces.

In general, subjects did better on handle positions such as 3/8 or 6/8 which provided the container with both horizontal and vertical stability.

In the Drury *et al.* industrial survey (1982) data were collected on hand positions used by materials handlers on box-like containers on a sample of over 2000 container movements.

For two-handed movements, there were 81 possible pairs of hand positions but the great majority of hand-position pairs recorded were only of a relative few of these 81 possibilities. Manual materials handlers apparently use only a small variety of hand positions, the most frequent being:

Position 3/7	43·7%
Position 1/9	9·2%
Position 8/8	8·7%
Position 7/9	7·9%

Hand positions 3/7 and 7/9, both of which fulfil the horizontal-plus-vertical-stability criterion derived from the laboratory, were associated with light but bulky containers. The 'two hands under' position, 8/8, was associated with containers which were compact in the fore-and-aft dimension and in height but heavy. this same position was also associated with taller and heavier people.

Between these two studies, recommendations could be made for handle positions and angles, but such recommendations would be based only on male student subjects holding containers at waist height. The industrial survey showed that most movements start or end at this position but that a substantial minority of movements involved boxes starting or ending anywhere between floor and shoulder height. Optimum handle angles would certainly be expected to change with task height (W. J. Nielson 1978, personal communication); there was no indication that optimum positions would not also change.

The study reported here was undertaken to provide more broadly based recommendations. The container was held at three heights (floor, waist and shoulder) and the subject sample was increased to 15 males and 15 females, all manual materials-handling workers.

2. Methodology

2.1. *Subjects*

Thirty subjects, fifteen males and fifteen females, were recruited from local industry. Their age, height, weight and job-experience characteristics are shown in table 1. While height and weight are representative of the range found in an industrial population, the distribution of age and experience are typical of manual materials handlers—young and moving on rapidly to other jobs.

2.2. *Materials*

Two plywood containers measuring 400 mm × 400 mm × 400 mm had handle attachment points in all nine positions shown in figure 1. One container weighed 9 kg and one 13 kg. These weights are lower than in the previous laboratory study and were chosen to be more consistent with the data on container weights in the industrial survey. As in the previous experiment, handles were designed to pivot so that 'natural' handle angles could be measured. However, rather than pivoting freely, the handles were arranged to pivot initially but lock when a force was applied. This gave a more realistic feel to the handles. Forces on the handles were measured by using hand dynamometers for the actual handles and only allowing a hook grip.

Six handle positions were used, based on both laboratory and field data, as given in table 2.

Photographs were taken from each side with two 35 mm cameras with a background of a black grid on a white wall to allow subsequent measurement of body and container angles.

A Beckman (Model R611) dynagraph was used to record heart rate and the force exerted by each hand on the hand-dynamometer handle.

Table 1. Subject characteristics.

Statistic	Male				Female			
	Minimum	Mean	S.D.	Maximum	Minimum	Mean	S.D.	Maximum
Age (years)	19	23·5	3·20	30	16	25·9	9·73	57
Height (m)	1·70	1·80	0·064	1·96	1·57	1·66	0·053	1·75
Weight (kg)	70	78·7	9·39	108	51	64·3	10·16	90
Job experience (months)	1	25·3	29·15	120	1	28·8	38·05	120

Table 2. Reasons for choice of handle positions.

Handle position	Studied in Coury and Drury (1982)	Reasons for choice
1/9	No	Very frequent in survey
8/8	Yes	Very frequent and lowest survey
3/6	No	One of best in laboratory study
3/8	Yes	One of best in laboratory study
6/8	Yes	One of best in laboratory study
2/2	No	Usual handle position where used

2.3. *Procedure*

Each subject was medically examined, briefed and had electrodes attached for heart-rate measurement. Each then performed 36 holding trials comprising all combinations of two container weights, three task heights and six handle positions. At the start of each trial, the subject lifted the container 20–50 mm from an adjustable stand at the correct height. Each trial lasted 25 s with a 95 s rest between trials. During each trial, the subject held the container by the handles at either floor, waist or shoulder height. Floor height was defined as having the bottom of the box just clear of the floor (20–50 mm in practice). Waist and shoulder heights were defined as having the centre of gravity of the box level with waist or shoulder. Subjects were given instructions and feedback to ensure consistency of holding heights. These task heights were chosen to conform to the many lifting studies which have used floor, waist and shoulder heights (see, for example, Snook 1978).

Subjects completed all conditions in about 1·5 hours. (After this experiment, they also took part in another, shorter experiment on one-handed lifting.)

2.4. *Experimental design*

The design had two genders (male and female) with 15 subjects in each group. Nested within genders (G) were three factorial variables, task height (H), container weight (W) and handle position (P). Subjects were given a choice of which hands to use on which handles (e.g. 3/6 or 6/3) as only a small effect of hands was found in the previous study. Twenty-eight out of the thirty subjects had their left hand uppermost. For those who did not, the data presented here have been transposed left for right so that the upper hand can be referred to as 'left' throughout this paper. The 36 trials were presented in a different random order to each subject.

Three sets of indices were used as before.

(1) Biomechanical indices (see figure 2):
   (a) Handle angle (HA): the angle between the handle and the horizontal.
   (b) Box angle (BA): the angle between the bottom of the box and the horizontal.
   (c) Wrist deviation angle (WDA): the angle between the lower arm (ulna) and the third metacarpal.
   (d) Slippage angle (SA): the angle between the handle axis and a line at 90° to the third metacarpal. (This represents the degree to which the subject fails to grip the handle with the whole width of the hand.)
   (e) Elbow angle (EA): the angle between midlines of lower arm and upper arm.
   (f) Shoulder angle (SHA): the angle between the midline of the upper arm and the line joining shoulder and hip joints.
   (g) Waist angle (WA): the angle between the shoulder–hip line and the hip–knee line.
   (h) Knee angle (KA): the angle between the hip–knee line and the midline of the lower leg.
   (i) Force at the handle (FH): the pulling force, the kilogrammes, exerted by each hand on the handle. This was measured from the output of the hand dynamometer which comprised each handle. Separate forces were measured for left and right hands.

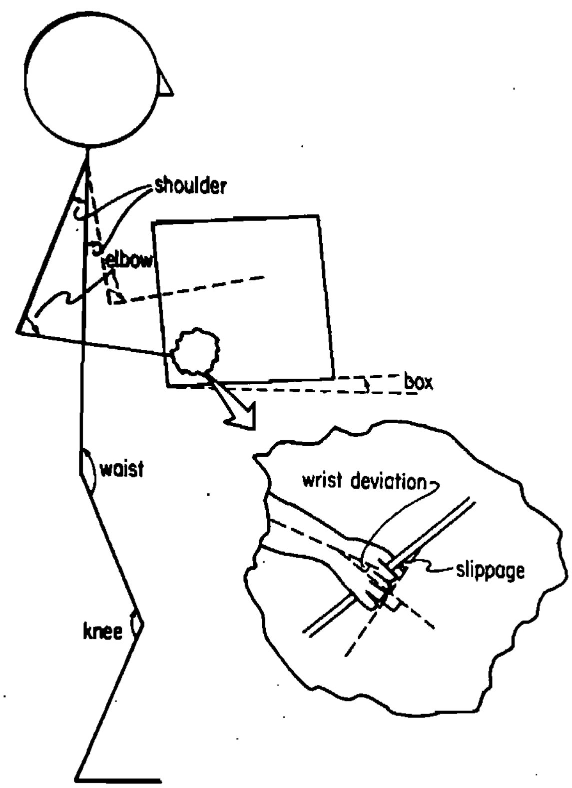

Figure 2. Definitions of angle measured.

(2) Physiological index:
Heart rate (HR): average measured during the last 15 s of the trial.

(3) Psychophysical indices:
(a) Rated perceived exertion (RPE): Borg's scale rated after each trial.
(b) Body part discomfort frequency (BPDF): frequency of non-zero ratings on Corlett and Bishop's (1976) scale, rated after each trial.
(c) Body part discomfort severity (BPDS): mean severity of all non-zero ratings on the above scale.

All the angular measures were digitized from the side-view photographs using a Hewlett-Packard 9825A computer with digitizer.

Analyses of variance were performed for each variable using the BMDP package. Following the earlier experiment, an intercorrelation matrix of all the variables measured was produced using the SPSS package.

3. Results

Before the details of the results can be given in such a complex experiment, the pattern of significance of the findings needs to be examined. The significance levels of all main effects and interactions are shown in tables 3 (biomechanical indices) and 4 (physiological, psychophysical and forces indices). The effects of task height and hand position are highly significant in almost all the anlayses. Their interaction ($H \times P$) is also significant in most analyses. Gender has almost no effect.

3.1. *Biomechanical indices*

The major purpose of this experiment was to find the effect of task height on handle use. Because of the large number of significant effects of the $H \times P$ interaction, the overall H effect is presented for the angular variables in figure 3. Figure 3(*a*) shows gross-body-postural variables while figure 3(*b*) shows upper-limb variables. As can be seen from figure 3, the gross body posture changes considerable with task height. At floor level, knee and waist are flexed. At waist level, knees and waist are in an upright posture (extended) while at shoulder height there is even a backward lean. Arm posture changes from moderately extended elbows and moderately flexed shoulders at floor height through increased flexion at each joint at waist height to sharply flexed elbows and less flexed shoulders at shoulder height. The box tilts back progressively as task height increases while the handles move from almost horizontal at floor height to almost vertical at the other two heights. Wrist deviation is non-zero, in contrast to the previous experiment, as handles could not rotate after the subject had achieved a suitable position and applied a force. All wrist deviations were ulnar, and all increased away from waist height. Slippage was small and relatively constant over all task heights.

The upper limbs showed differential effects of left and right. The left hand (always the upper hand on the box) gave more vertical handle angles, higher ulnar deviations of the wrist, a more flexed elbow and a more extended shoulder, all of which would be expected with higher handle positions on the box.

In order to show the handle-position effect at each task height with so many variables, Neuman–Keuls tests were made on the means of each variable measured at each handle position at each task height. There were a large number of significant differences ($p < 0{\cdot}01$) given in detail in table 5. In general, the asymmetric positions with

Table 3. Summary of analyses of variance of biomechanical indices.

Source of variance	HA, left	HA, right	BA	WDA, left	WDA, right	SA, left	SA, right	EA, left	EA, right	SHA, left	SHA, right	WA	KA, left	KA, right
Genders (G)			*							***				
Heights (H)	***	***	***	***	***	***		***	***	***	***	***	***	***
Weights (W)						*	**		*		*			
Positions (P)	***	***	***	**	***		**	***	***	***	***	***		
$G \times H$					***		*			***	***			
$G \times W$														
$H \times W$	***	***			**			*	**	***	***		*	**
$G \times P$					**			***	**	**	***	*		
$H \times P$	***	***	***	***	***	***		***	***	***	***	***	*	
$W \times P$														
$G \times H \times W$														
$G \times H \times P$					**			**		***	***			
$G \times W \times P$														
$H \times W \times P$					*									
$G \times H \times W \times P$														

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4. Summary of analyses of variance of physiological, psychophysical and force indices.

	Force, left	Force, right	Heart rate	RPE	BPDF	BPDS
Genders (*G*)						
Heights (*H*)	***	***	***	***	***	***
Weights (*W*)	***	***	***	***	**	***
Positions (*P*)	***	***	***	***	*	***
$G \times H$	*	**		*		
$G \times W$				*		
$H \times W$	***	***		**		
$G \times P$				*		
$H \times P$	***	***	***	**		
$W \times P$						
$G \times H \times W$						
$G \times H \times P$	*					
$G \times W \times P$						
$H \times W \times P$						
$G \times H \times W \times P$						

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 5. Summary of significant differences between handle positions at each task height.

	Task height		
Variable	Floor	Waist	Shoulder
HA, left	1/9 > 3/7 3/7 > 2/2, 3/8, 6/8, 8/8	2/2, 3/7, 3/8 > 6/8 All > 8/8	1/9, 3/7 > 6/8 All > 8/8
HA, right	1/9 > 2/2, 3/7, 3/8, 6/8 8/8 > all	1/9, 2,2, 8/8 > 3/7 2/2 > all	2/2 > all 8/8 > 3/7
SA, left	3/8, 6/8 > 2/2 3/7, 3/8, 6/8 > 8/8	—	—
SA, right	—	—	—
WDA, left	—	—	1/9, 2/2 > 3/7, 3/8, 6/8, 8/8
WDA, right	3/7 > all	—	—
EA, left	All > 1/9	All > 1/9 2/2 > 3/7, 3/8, 6/8, 8/8 6/8, 8/8 > 3/7, 3/8	All > 1/9 3/7, 3/8, 6/8, 8/8 > 2/2 3/7, 3/8, 6/8 > 8/8
EA, right	—	1/9 > all 3/7 > 2/2 3/8, 6/8, 8/8 > 2/2, 3/7	1/9 > all 3/7 > 2/2 3/8, 6/8, 8/8 > 2/2, 3/7
SHA, left	All > 1/9 3/7, 3/8, 6/8 > 2/2, 8/8	3/7, 3/8, 6/8 > 1/9, 2/2, 8/8	2/2, 3/7, 3/8, 6/8 > 1/9, 8/8 3/7, 3/8 > 2/2, 6/8
SHA, right	All > 3/7	1/9 > all	1/9, 2/2 > all
WA	2/2, 3/7 > 1/9, 6/8, 8/8 3/8 > 6/8	—	—
FH, left	6/8, 8/8 > 1/9, 3/8	All > 1/9	All > 1/9 3/7, 3/8, 6/8 > 2/2, 8/8
FH, right	3/7, 6/8, 8/8 > 2/2	1/9 > 3/7, 3/8, 6/8 2/2, 8/8 > 3/7	1/9 > all 3/8, 6/8, 8/8 > 2/2, 3/7
HR,	2/2, 3/7 > 3/8, 6/8	2/2 > 3/8, 6/8	8/8 > all
RPE	3/7 > 1/9, 3/8, 6/8, 8/8	—	—

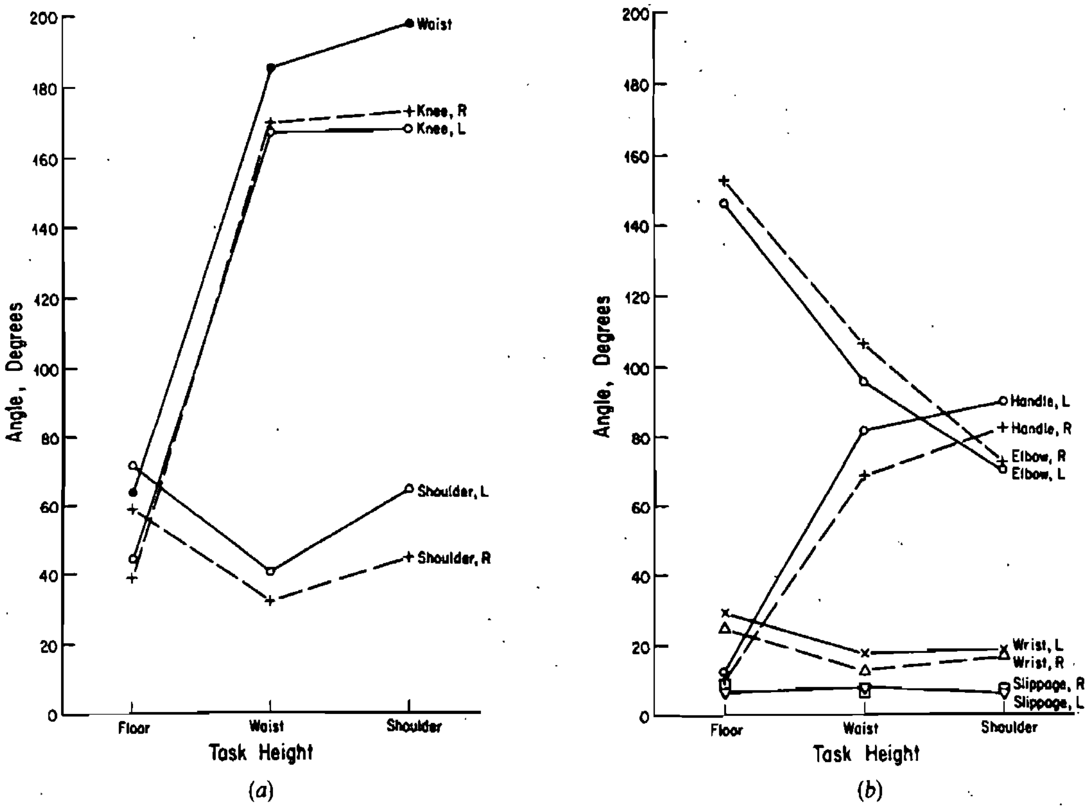

Figure 3. Effect of task height on body and box angles.

the forward hand higher (3/7, 3/8, 6/8) formed a group, the symmetric positions (2/2, 8/8) formed another, while the position which had the forward hand lower (1/9) was usually different from either group. Other tests of left hand versus right hand (not presented in table 5) gave the expected result that left- and right-hand angles were very similar in symmetrical positions (2/2 and 8/8) and quite different in all asymmetric positions.

Forces on the handles are presented as $H \times P$ interactions in figure 4, as well as in table 5. The forces exerted by the left and right hands are least in the floor position, where the two forces summed to almost exactly the container weight, showing that forces are almost exactly vertical and merely supporting the weight. The averages over the two container weights are shown in figure 4 and hence the average container weight would be 11 kg. Lines are shown at 5·5 kg for each hand to demonstrate the closeness of the forces to these 'expected' values at floor level. In the waist position, and to a lesser extent in the shoulder position, forces are higher because much of the force is now directed towards the body with the container supported both by body/container friction and the upward component of the forces at the handles. The force disparity between the hands was large for the most asymmetrical hand position (1/9) with the lower hand (right) supporting most of the weight.

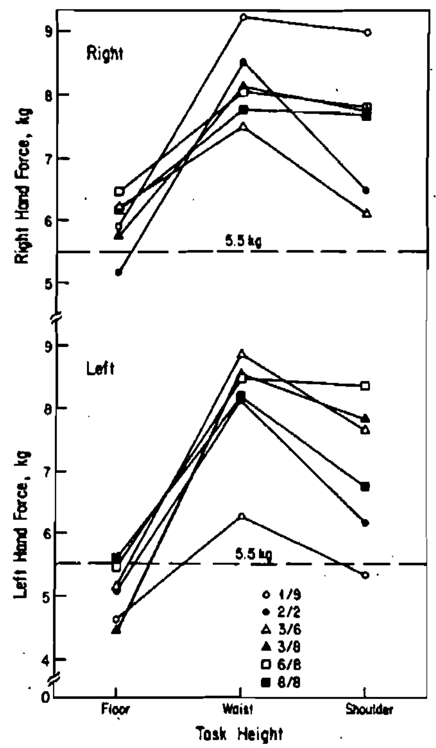

Figure 4. Effects of task height and handle position on left- and right-hand forces.

3.2. *Physiological and psychophysical indices*

Heart rates for comparable handle positions at waist height were slightly higher (96–101 beats/min) than in the previous study (94–99 beats/min) despite a reduction in container weight. This may have been due to the changed subject population. Handle positions 3/8 and 6/8 can be seen in figure 5 and table 5 to give clearly lower heart rates than the other positions for floor and waist levels while the symmetrical positions (2/2 and 8/8) fared rather poorly. Rated perceived exertion (figure 6), this time closely comparable in value to the previous study, showed the superiority of 3/8 and 6/8 with 2/2 and 8/8 only poor at the shoulder level. Both heart rate and rated perceived exertion show the waist level as least strenuous but the highest heart rates are found at shoulder level and the highest RPE values at floor level.

Body part discomfort frequency and severity were lowest in the waist position (figure 7). Handle position effects for these variables are shown in figure 8 which again emphasize the utility of positions 3/8 and 6/8. The frequency of citing particular body parts was quite low, and hence there were too few data to analyse the frequency or severity at each body part at each handle position. Hence, only the rates of citing each body part over the whole experiment are presented in table 6. It is interesting to note that the body parts rated worst on frequency were in the upper limbs with the order being upper arm (worst), lower arm, shoulder and hand. In severity the four worst were all in the torso with the order being lower back (worst), mid-back, upper back and shoulder. A further finding was that buttocks, thighs and legs were stressed only when holding at floor level, presumably due to the squatting posture.

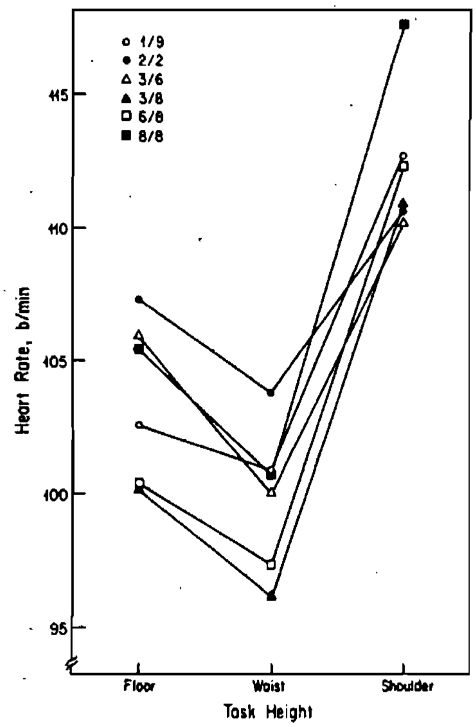

Figure 5. Effect of task height and handle position on heart rate.

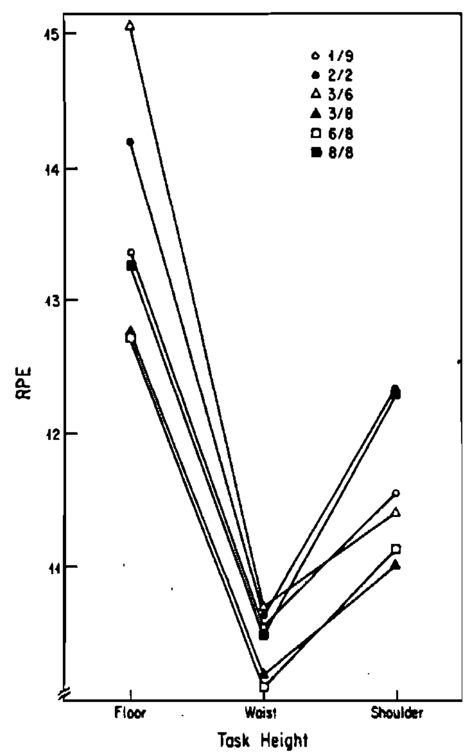

Figure 6. Effect of task height and handle position on rated perceived exertion.

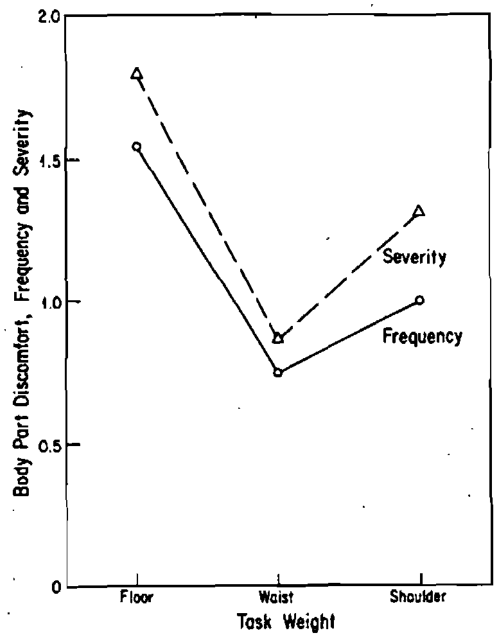

Figure 7. Effect of task height on mean body part discomfort.

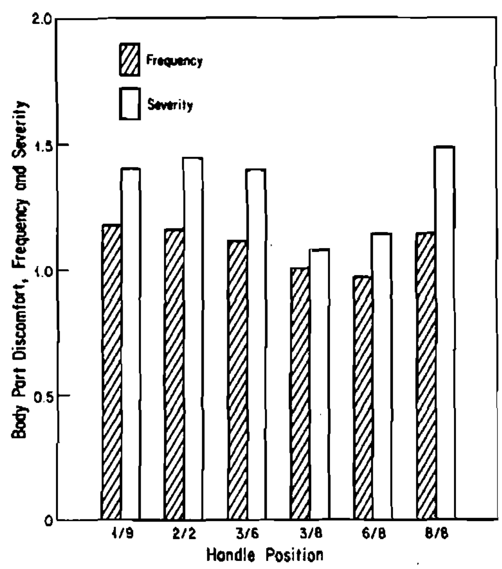

Figure 8. Effect of handle position on mean body part discomfort.

Table 6. Discomfort in each body part. Frequency is the percentage trials on which a non-zero reading was obtained. Severity is the mean value of non-zero readings.

Body part	Frequency	Severity
Upper limbs		
Shoulders	7·7	2·28
Upper arms	10·8	2·17
Lower arms	8·1	2·14
Hands	7·3	2·24
Trunk		
Neck	2·8	1·73
Upper-back	5·0	2·28
Mid-back	3·9	2·48
Lower back	4·7	2·67
Buttocks	0·9	1·27
Lower limbs		
Thighs	1·8	0·86
Lower legs	2·1	0·69

Interrelations between the set of 19 variables were explored by constructing an intercorrelation matrix using the 18 $H \times P$ means of each variable. In all, 129 of the 171 correlation coefficients were significant at $p < 0{\cdot}05$ or higher, showing a high degree of interrelationship between the variables. The RPE scores and the BPD scores all intercorrelated at $r = 0{\cdot}9$ or better and all correlated, negatively, with hand forces at $r = 0{\cdot}75$ or better. Heart rate did not correlate significantly with any of these variables. Rather than present the whole intercorrelation matrix, a factor analysis was performed on it using the principal-components method with varimax rotation of factors.

Factor analysis with varimax rotation simplifies the underlying structure of an intercorrelation matrix by suggesting a few factors which correlate highly with different sets of the original variables. Three orthogonal factors accounted for 95·1% of the total variance with the variables giving high factor loadings as follows:

Factor 1 (74·8% of variance): high RPE, BPDF, BPDS; flexed knees and waist, low force in upper hand, extended shoulder for lower hand.

Factor 3 (13·4% variance): high force in lower hand, flexed shoulder for upper hand, low wrist deviation in upper hand.

Factor 3 (6·9% variance): high heart rate, extended knees and waist, flexed elbows, vertical angles.

The first factor appears to be identified with the squatting position and, perhaps, handle position 3/7. The second is more difficult to interpret but appears to represent handle position 1/9. Factor 3 represents the two upright task heights.

4. Discussion

As in the previous research, the effect of handle position was large. In the measures of force and stress, the difference between the best and the worst handle positions was closely comparable to the difference between loads of 9 and 13 kg. It is instructive to compare the relative magnitudes of the handle-position effect and the weight effect. In table 7 the size of the handle-position effect was computed for each variable as the

Table 7. Relative magnitudes of handle-position effect and container-weight effect.

Variable	Handle-position effect (worst–best)	Weight effect (13–9 kg)	Handle-position range as equivalent percentage container-weight change
FH, left	1·467	1·756	37
FH, right	2·027	1·355	67
HR	5·517	4·659	52
BPDF	0·211	0·309	30
BPDS	0·406	0·307	59
RPE	1·067	1·719	28

difference between the best and the worst handle position. Similarly, the size of the box-weight effect was the difference between the mean value at 9 kg and the mean value at 13 kg. The final column expresses the change in container weight which would be equal in magnitude to the difference between the best and worst handle positions. All variables show that handle position can alter the cost to the worker as much as a 25% change in box weight, with half of the indices, including heart rate, showing the equivalent of a 50% change. It should be remembered that the handle positions were chosen to be reasonable ones and not chosen to include obviously poor positions.

Task height had, as expected, a very large effect on all indices. In particular, the upper limbs and the container interacted in different ways at the three heights. At the floor position arms were extended, wrists highly deviated in the ulnar direction and handles almost horizontal on an almost horizontal box. All the box weight was hung from the two hands. At the higher task heights, the box was clasped to the body with almost vertical handles on a tilted box. Wrist deviation was again present but smaller in magnitude than at the floor level. The total force (left hand plus right hand) was almost 50% higher than the container weight.

In choice of 'good' handle positions, it is possible to extend the results of the earlier experiment to heights other than waist height. Critical evaluation variables are heart rate, RPE, BPD and wrist deviation. The symmetrical positions (2/2 and 8/8) and the position found most frequently in the industrial survey (3/7) fared poorly on one or more of the indices. Positions 3/8 and 6/8 emerged clearly from the 'cost to the subject' variables as being good positions. The reversed position (1/9) gave no clear evidence of being good or poor, only of making the expected changes in arm angles and forces. Positions 3/8 and 6/8 confirm the previous findings of horizontal and vertical stability as being necessary attributes of a 'good' handle position. They are also the handle positions recommended in the Coury and Drury (1982) paper on the basis of waist-height holding only. As these are better than the reversed position (1/9), a tentative conclusion is that in addition to horizontal and vertical stability, it is important to have the upper arm further from the body than the lower arm.

However, results of this experiment confirm the previous laboratory study in showing that the symmetrical positions (2/2, 8/8) minimize hand forces. Where these forces become limiting, for example with heavy boxes or where lifting rather than holding or lowering is the required task, then a symmetrical position is recommenced. There is little to choose between 2/2 and 8/8 on any of the indices.

Choice of optimum handle angles to the box is considerably more difficult than in the previous experiment. Box handle angle itself has large changes with task height and, in addition, wrist deviation and slippage must be taken into account. The sense of both wrist deviation and slippage is such that the box-handle angle would have to be increased by both angles to give a neutral wrist position and no handle/hand slippage. Table 8 brings together the sum of these three angles for both left and right hands. At floor height, an angle of 40–60° is required, while at waist and shoulder heights, an angle of 80–120° is indicated. It is interesting in table 8 that when an angle is measured on both left and right hands, or on the same left-hand position with different right-hand positions, there was a reasonably close correspondence between the angles. A general recommendation from these data is difficult to make. Any recommended angle will be subject to wild deviations at 'wrong' task heights. Perhaps the best compromise recommendation for holding tasks is an angle of around 70°, minimizing deviations at all three heights.

Table 8. Angles of box to handle to give neutral wrist deviation and no hand/handle slippage, for the seven hand positions tested.

Hand position on container	Floor height (mm)	Wrist height (mm)	Shoulder height (mm)
1	57	106	111
2	48, 48	112, 108	105, 121
3	58, 55	113, 112	127, 124
6	47	101	121
7	25	79	100
8	42, 41, 40, 50	91, 83, 85, 89	116, 103, 104, 110
9	52	84	106

From the work so far, it appears that handles in positions 3, 6 and 8 on each side of a box would have great utility. A worker would be able to choose 3/8 or 6/8 for most box movements, with the additional option of using 8/8 for heavy containers near floor level. Handle angle should be about 70° for all handles. All of the work reported here and earlier (Coury and Drury 1982) assumes that a handle will be approximated by a cylinder of about 25–40 mm diameter and about 115 mm long (see Drury (1980) for details). If the handle is a straight-sided cut-out in the side of the box, then this should still be a reasonable assumption. However, an odd-shaped cut-out, for example a circle or an ellipse, may be another possibility to allow variation of 'handle angle' with task height. Before such a device is postulated, dynamic tests rather than static tests of straight handles need to be undertaken. These are now in progress.

The three factors determined from the factor analysis proved interesting in that there were two distinct 'high cost to the worker' factors. Factor 1, a squatting factor, was associated with high RPE values and high body part discomfort: squatting is uncomfortable. Factor 3, an upright factor, was not uncomfortable but had high heart rates (as noted in figure 4). Presumably the upright task postures, particularly holding a container at shoulder height, give more cardiovascular stress due to statically supporting the arms at greater heights causing greater blood pressures. It is interesting that recent attempts to use RPE in other than the dynamic tasks for which it was originally designed are beginning to discover new dimensions of perceived workload by studying how heart rate and RPE responses differ.

Finally, it is useful to note that box weight again had very little effect on the handle and body angles. Combined with the previous result of almost no effect of box size, it means that recommendations for handle positions and angles can be given with some confidence to cover a wide range of manual materials-handling containers, although extremely heavy containers may require symmetrical handles as noted earlier.

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On a testé six positions différentes des poignées dans une tâche de portage de conteneurs à deux poignées. Les observations ont été faites avec le conteneur au sol, à hauteur de la ceinture et à hauteur de l'épaule. Quinze sujets hommes et 15 sujets femmes, rous manutentionnaires ont participé à l'expérience. On a observé des effets importants sur les forces exercées, la fréquence cardiaque et divers indices psychophysiques selon la position des poignées, comparés aux effets produits par une variation de 25% dans le poids des conteneurs. Ainsi qu'il avait été montré dans une étude antérieure (au niveau de la ceinture seulement) on peut affirmer que la position des poignées qui permet une bonne stabilité horizontale et verticale, est meilleure que la position symétrique. Les angles optimum poignée/conteneur varient fortement avec le poids: ils sont presque horizontaux au niveau du sol et presque verticaux au niveau de la ceinture et de l'épaule.

Sechs Anordnungen von Handgriffen beim zweihändigen Halten eines Behäleters wurden bei Positionierung des Behälters am Boden, in Gürtel- und Schulterhöhe untersucht. Je fünfzehn männliche und weibliche Personen aus dem Bereich der Lastenhandhabung nahmen an der Untersuchung teil. Die Auswirkungen der Anordnung von Handgriffen auf die ausgeübten Kräfte, die Herzschlagfrequenz und die psychologischen Parameter waren groß im Vergleich mit denjenigen, die durch eine Veränderung der Behältergewichte um 25% bewirkt wurden Ähnlich wie in vorangehenden Untersuchungen (lediglich in Gürtelhöhe) und in industriellen Untersuchungen, waren Handgriffanordnungen mit resultierender sowohl horizontaler als auch vertikaler Stabilität besser als symmetrische Anordnungen. Optimale Winkel der Handgriffe relative zum Behälter veränderten sich stark mit der Positionierungshöhe des Behälters, wobei fast horizontale Winkel bei der Bodenhöhe und fast vertikale Winkel bei der Gürtel- und Schulterhöhe resultieren. Anwendungsmöglichkeiten für die Gestaltung von Zugriffstellen an Behältern werden diskutiert.

両手を用いる荷物保持作業における取っ手の位置6種類について，容器が床の上，腰の高さ，そして肩の高さにある時について調べた。男性作業者15名と女性作業者15名が実験に参加した。取っ手の位置が力の大きさ，心拍数，及び精神物理学的指数に及ぼす影響を容器重量の25%の変化によって生ずる影響と比較を行った。以前の研究（腰の高さのみ）と産業調査で見られたと同様に，水平及び垂直方向両方の安定が得られる取っ手の位置が対称的な配置をした取っ手の位置よりも良い。容器と取っ手の最適な角度は作業の高さによって大きく変化し，床高においては水平に近い角度が，腰及び肩の高さでは垂直に近い角度が最適角度であった。容器の取っ手の設計について意味するところを論ずる。

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