Ergonomics

ISSN: 0014-0139 (Print) 1366-5847 (Online) Journal homepage: https://www.tandfonline.com/loi/terg20

Handle positions and angles in a dynamic lifting task Part 2. Psychophysical measures and heart rate

C. G. DRURY & J. M. DEEB

To cite this article: C. G. DRURY & J. M. DEEB (1986) Handle positions and angles in a dynamic lifting task Part 2. Psychophysical measures and heart rate, Ergonomics, 29:6, 769-777, DOI: 10.1080/00140138608968313

To link to this article: https://doi.org/10.1080/00140138608968313

Published online: 07 Jun 2007.

ERGONOMICS, 1986, VOL. 29, NO. 6, 769–777

Handle positions and angles in a dynamic lifting task
Part 2. Psychophysical measures and heart rate

By C. G. DRURY and J. M. DEEB

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

This paper continues the results of the experiment on handle positions and angles in lifting described in Part 1. Heart rate rated perceived exertion, and body-part discomfort were measured on 30 subjects lifting boxes from floor to waist, waist to shoulder and floor to shoulder. Movement distance had a large effect on all measures. A handle angle of 70° between box and horizontal was found better than an angle of 35°. Handle position differences were minimal. The design for cut-out handles on a box, presented in Part 1, was confirmed by these results.

1. Introduction

Part 1 of this paper described the angles of the elbow, wrist and hand/angle slippage in a dynamic lifting and lowering task. Part 2 presents the responses of the human to the same task in terms of the 'cost' of the activity to the operator.

Previous static holding tasks with different handle positions on boxes (Coury and Drury 1982, Deeb *et al.* 1985) showed that both task height and handle positions had a large effect on heart rate, rated perceived exertion (RPE, Borg 1962) and body-part discomfort (BPD, Corlett and Bishop 1976). At floor level and shoulder level all indices showed higher values (i.e., more strain) than at waist level, presumably because of the static muscular loads imposed by either bending the knees (floor) or holding the arms and load at a high level (shoulder). Asymmetric handle positions 3/8 and 6/8 (see Part 1 for handle position definitions) showed lower strain than symmetric positions 2/2 and 8/8 at all heights of holding. However, the symmetric positions gave the lowest hand forces because here the box was held almost entirely by the hands with very little box/body contact. In the asymmetric positions, the box was held against the body, reducing the vertical component of hand forces but increasing their overall value.

On the basis of these static tests, it was recommended that asymmetric positions (3/8 and 6/8) be used for all tasks except for lifting of heavy boxes near floor level where total hand forces may be limiting. Under these circumstances, either position 2/2 or position 8/8 was recommended.

In a dynamic lifting or lowering task, there is less opportunity to hold the box against the body, so that the static recommendations derived from holding tasks may not apply. Part 1 described the body's biomechanical response to a lifting/lowering task and concluded that handle positions of 6/8 with handle angles of 60° and 50° to the horizontal for these two positions gave the best match between hand and handle across task heights. The question asked in this part is whether the biomechanical recommendations are supported by the physiological and psychophysical cost variables.

The static task showed an effect of box weight, with 13 kg giving more strain than 9 kg, but no effect of subject gender. It also showed the RPE scores were larger than ten times the heart rate, presumably because subjects rated their exertion on the basis of local muscular fatigue as well as cardiovascular load. For a dynamic task, the RPE values should be closer to the value of ten times the heart rate than in the static task.

2. Methodology

A detailed methodology was given in Part 1 and will not be repeated here. Briefly, fifteen male and fifteen female manual materials handling workers took part in the experiment. Each subject performed eight lifting/lowering trials under each combination of three movement distances (floor to waist, waist to shoulder and floor to shoulder), two handle angles (35° and 70° to horizontal) and four handle positions (3/7, 3/8, 6/8 and 2/2). Trials were performed every 15 seconds to give two minutes of work, followed by rest for either two minutes or until heart rate had returned to resting level, whichever was longer. The box was a 400 mm cube of 11 mm plywood, weighing 11 kg. Handhold cutouts were cut into the sides of the box at each handle position and angle.

Measurements of interest in this paper were as follows:

(1) Physiological index
Mean heart rate measured over the duration of each of the two lifts for lifts 5 and 7 out of the 8 lifts.

(2) Psychophysical indices
(*a*) Rated perceived exertion (RPE): Borg's (1962) scale rated after each condition.
(*b*) Body-part discomfort frequency (BPDF): frequency of non-zero ratings on Corlett and Bishop's (1976) scale, rated separately for each side of the body after each condition.
(*c*) Body-part discomfort severity (BPDS): mean severity of all non-zero ratings on the above scale.
(*d*) Total time to perform lift, seconds.

Analyses of variance were performed on all measures. For those measures taken on each trial (heart rate and time to lift), a five-factor ANOVA was performed. The factors were gender (G), movement distance (D), handle angle (A), handle position (P) and trial (T). As the psychophysical measures were only taken at the end of each condition, they were subjected to a four-factor ANOVA with G, D, A and P. In all analyses, subjects were treated as a random factor nested within genders, with all other factors treated as fixed effects.

3. Results

Table 1 shows the pattern of significant results for all the measures. Movement distance was highly significant for all measures and gender was significant for all except the body-part discomfort measures. Trials (5 versus 7) was significant where it was included as a factor. No main effects of handle angle or handle position were seen.

Movement distance × handle position (D × P) interactions for the body-part discomfort measures are shown in figure 1. All showed a similar pattern of least discomfort for the waist to shoulder lift and most for the floor to shoulder lift. Within this pattern, all showed minimum discomfort with the symmetrical handle (2/2) for the floor to waist lift. For the waist to shoulder lift, all handle positions were closely grouped but 3/8 was always best. For lifting over the full distance, 3/7 was best in three out of the four measures. Previous work has already found asymmetric handle

Table 1. Significance of effects for physiological and psychophysical indices.

Factor	Heart rate	RPE	BPDF right	BPDF left	BPDS right	BPDS left	Time to lift
Gender (G)	***	**					***
Movement Distance (D)	***	***	***	***	***	***	***
Angle (A)							
Position (P)							
G × D							*
D × P			*		**	*	
G × D × P							*
G × D × A × P						*	
Trial (T)	***						***
G × T	*						
D × T	***						
A × T	*						

*, $P<0.05$; **, $P<0.01$; ***, $P<0.001$.

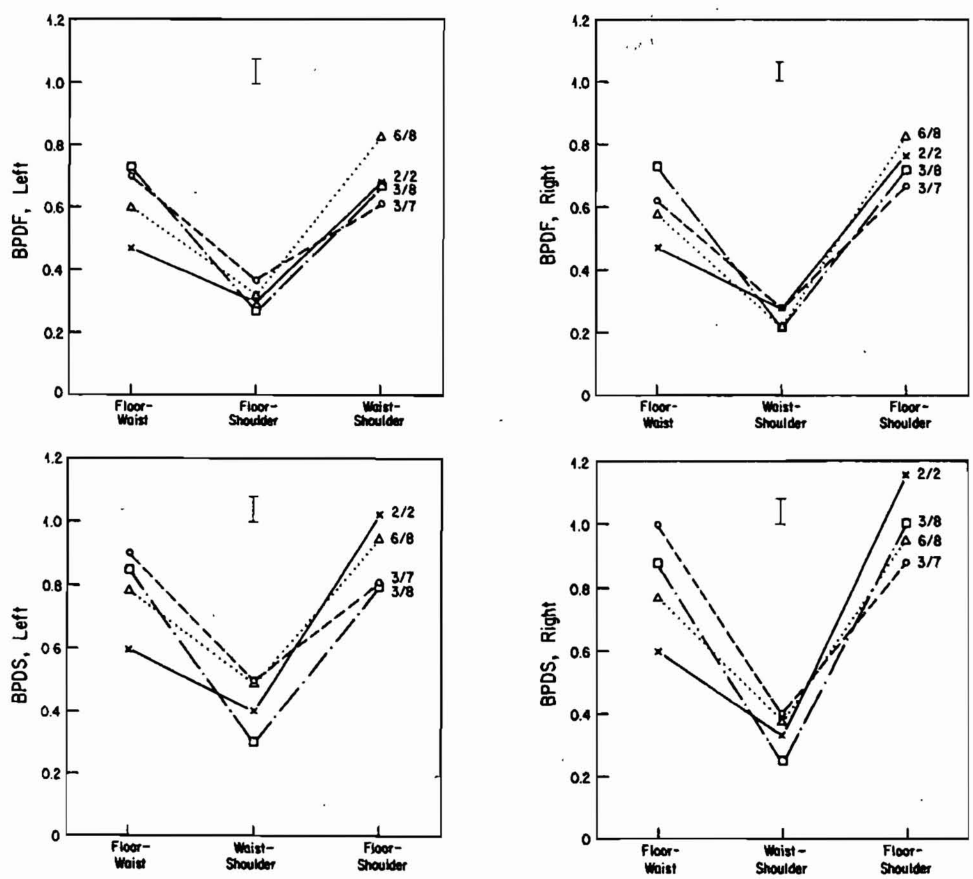

Figure 1. Movement distance × handle position interaction for body-part discomfort frequency (BPDF) and severity (BPDS). Bars on all figures represent standard error of means plotted.

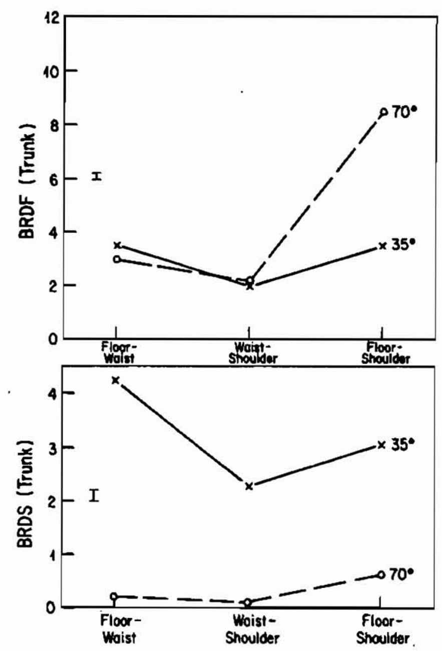

Figure 2. Handle angle × movement distance interaction for trunk body-region discomfort frequency (BRDF) and severity (BRDS).

positions better overall, but has associated symmetrical positions with heavier and lower lifts; this experiment tends to confirm that finding.

When the body-part discomfort measures were broken down by body part, the legs and thighs gave the largest values. Because the legs were expected to have their lowest discomfort in the waist–shoulder lift (where they were stationary) it was deemed advisable to analyse each body part in greater detail. The seventeen body parts on the response sheet made too fine an analysis, with many body parts rarely having non-zero readings. Hence, the body was broken into five body regions as follows:

Trunk: Neck, upper back, mid-back, lower back, buttocks.
Arms (left and right): shoulders, upper arm, lower arm, hand.
Legs (left and right): thighs, legs.

Body-region discomfort frequency (BRDF) and severity (BRDS) were calculated by summing across all 30 subjects for each region. Analyses of variance (factorial: D × A × P) were performed for BRDF and BRDS in each region with the results shown in table 2. Movement distance (D) and handle angles (A) and/or the D × A interactions were significant for all variables, whereas handle position (P) and its interactions were almost never significant.

The D × A interactions are shown in figures 2–4. Frequency and severity each showed the same pattern of minimum pain/discomfort at waist–shoulder for trunk and legs and a maximum for this movement distance for arms. The 70° handle angle showed much less severity than the 35° angle for all regions at all distances. For arms and legs, pain/discomfort frequencies were very similar at both angles and on both sides of the body, but for the floor–shoulder task (for arms) at 70° handle angle, an unexpectedly high pain/discomfort frequency occurred.

Table 2. Significance of effects for body-region discomfort frequency and severity scores (BRDF and BRDS respectively).

	Trunk		Arm				Leg			
			Right		Left		Right		Left	
Factor	BRDF	BRDS	BRDF	BRDS	BRDF	BRDS	BRDF	BRDS	BRDF	BRDS
Movement										
Distance (D)	**		*	**	***		***	***	***	**
Handle angle (A)	*	**		***		*		***		***
Handle position (P)										
D × A	**			*				**		**
D × P									*	

*, $P<0·05$; **, $P<0·01$; ***, $P<0·001$.

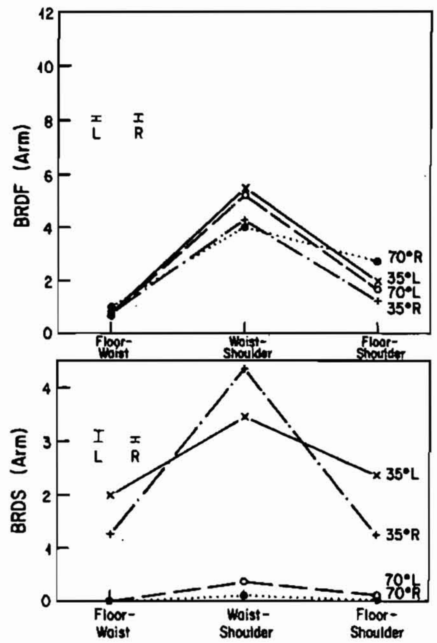

Figure 3. Handle angle × movement distance interaction for arm body-region discomfort frequency (BRDF) and severity (BRDS).

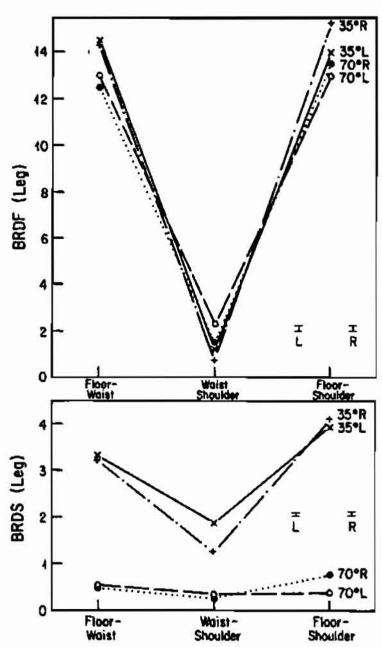

Figure 4. Handle angle × movement distance interaction for leg body-region discomfort frequency (BRDF) and severity (BRDS).

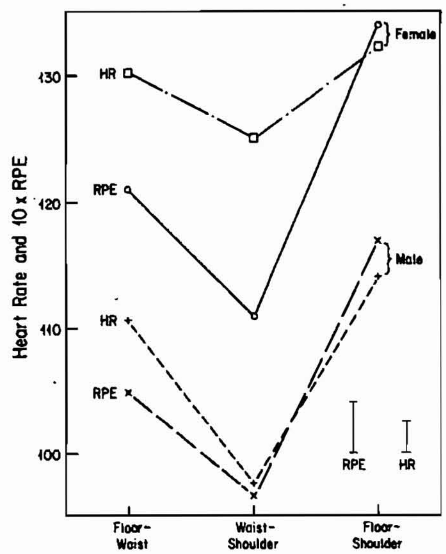

Figure 5. Heart rate and ten-times-RPE as a function of gender and movement distance.

Heart rate and RPE showed similar effects in figure 5. RPE should be one-tenth of heart rate for dynamic tasks, a finding confirmed closely in figure 5. The main discrepancies were for females on the two shorter distance where they tended to rate their exertion lower than would be expected. The three movement distances were in the same order as found for the overall BPD scores. Females were significantly more stressed than males, in contradistinction to the results of static tests reported earlier where no gender differences were found.

Time per lift showed the same pattern of height and gender as RPE and heart rate (figure 6). Females took longer than males for the two shorter lifts and even longer for the most stressful lift (floor–shoulder). The effect of trials on time per move was small (1·31 seconds for Trial 5 and 1·39 seconds for Trial 7) but significant. Subjects slowed down slightly on the later trial. There was a trial effect on heart rate, with an increase of

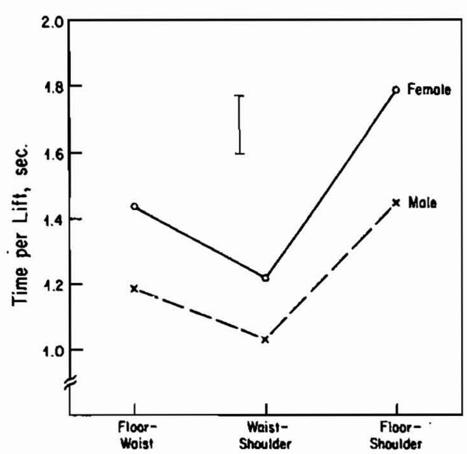

Figure 6. Gender and movement distance effects for time per lift.

about 3 beats/minute over the two trials measured. This difference was slightly greater for females than males and varied somewhat in proportion to the stressfulness of the lift. Such effects show that the task was a difficult one, not at steady state, and proportionally more difficult for lifts involving floor level and female workers.

4. Discussion and conclusions

Gender effects were significant for physiological cost (heart rate), perceived exertion (RPE) and speed of lifting (time per lift). These findings are not new in dynamic tasks but do point out the distinction between dynamic and static tasks since no such effects were found in earlier static experiments.

Heart rate was generally higher in this dynamic task than in the earlier static tasks, as would be expected by the body mass moved, especially in lifts from floor level. During the two-minute work period, the heart rate had almost reached a stable state. The mean at the 5th lift was 118·2 beats/minute while at the 7th lift it was 121·6 beats/minute RPE was closely in line with ten times the heart rate, again as in the literature for dynamic tasks. In previous static tasks, RPE was of the same order of magnitude as found in this experiment even though heart rate was lower. The divergence between heart rate and RPE under static conditions is confirmed.

Body-part discomfort was largely influenced by scores in the legs and thighs. These were much higher for lifts from floor level. The lift from waist to shoulder, however, showed the expected result that arm work was the chief source of pain/discomfort. The body-region discomfort scores used here seem to be a reasonable compromise between the specificity of the individual body parts and the data summarization ability of the overall BPDF and BPDS scores. Body-region discomfort certainly showed up a handle angle effect in severity and the differences in pattern of height of lift effects among the body regions. Overall, the BPDF and BPDS scores were comparable (when left and right are summed) to those obtained in the static tasks.

If handle angle effects pointed reasonably clearly to 70° as being a better angle than 35°, what can be said of handle position effects? All handles are rather similar in their effects on body-part discomfort, but small patterns do emerge. For floor to waist movements, handle position 2/2 was best in all cases, reconfirming the previous findings from the static task and an industrial survey (Drury *et al.* 1982) that a symmetrical position is preferred close to floor level. For the waist to shoulder movement, the lowest BPD in each case was for position 3/8 while over the largest movement distance studied (floor to shoulder), position 3/7 was best. Hence, overall an asymmetric position would be chosen. However, the absolute size of these differences is small and there is no confirming evidence in terms of cardiovascular effects (HR or RPE).

It appears that while the 'cost' measures used in this paper support the biomechanical recommendations for handle angles, they neither support nor refute those recommendations for handle position at any practical level.

Hence the conclusions of Part 1 still stand. For general-purpose manual materials handling, a box with hand-hold cut-outs enabling operators to use an asymmetrical hand position (6/8) is recommended. The angles of the handles should be 60° for position 6 and 50° for position 8. The box proposed in Part 1 would allow an symmetric position (8/8) to be adopted for boxes at floor level, which would be beneficial according to the physiological and psychological cost measures.

Acknowledgment

This study was supported by the National Institute for Occupational Safety and Health, Division of Safety Research. The NIOSH project officer was T. Pizatella.

Cet article relate la deuxième partie de l'étude sur la position des poignées et des angles lors d'une activité de levage de boîtes (sol-ceinture, ceinture-épaule et sol-épaule). Chez 30 sujets, on a déterminé la fréquence cardiaque, l'effort perçu et l'inconfort local corporel. L'ampleur du mouvement avait un effet important sur toutes les variables mesurées. Un angle de poignée de 70° entre la boîte et l'horizontale s'est avéré meilleur qu'un angle de 35°. Les différences entre les positions des poignées étaient minimes. La supériorité du modèle comportant des poignées profilées a été confirmée avec ces résultats.

Die Studie setzt die Beschreibung der Resultate bezüglich des Experimentes der Griffpositionen und der Winkel beim Anheben, die im Teil 1 beschrieben wurden, fest. Der Herzschlag, die bewertete wahrgenommene Anstrengung und die Beschwerden an den Körperteilen wurden an 30 Versuchspersonen, die Kisten vom Boden zur Taille, von der Taille zur Schulter und vom Boden zur Schulter anhoben, gemessen. Die Bewegungsstrecke hatte einen großen Einfluß auf die Messungen. Ein Winkel von 70° zwischen dem Griff und der Horizontalen wurde besser eingestuft als ein Winkel von 35°. Die Unterschiede zwischen den Griffpositionen waren minimal. Der Entwurf von ausgeschnittenen Griffen in einer Kiste, vorgestellt im Teil 1, wurde durch die Ergebnisse bestätigt.

本論文は第1報で述べた持ち上げ作業における取っ手の位置と角度についての実験結果を引き続き報告するものである。被験者30名に対し，床面から腰の高さまで，腰の高さから肩の高さまで，そして床面から肩の高さまで箱を持ち上げさせた時に，心拍数，知覚された評定難度，及びからだの部分的不快感について測定を行った。移動距離はすべての測定値に大きな影響を及ぼした。箱と水平面との間で取っ手角度が70°となるものが35°のものより良い結果が得られた。取っ手の位置の差はわずかであった。第1報で報告した箱上の切り込み型取っ手の形状がこれらの結果より明確になった。

References

Borg, G. Z. V., 1961, *Physical Performance and Perceived Exertion* (Copenhagen: Ejnar Munksgaard).

Corlett, E. N., and Bishop, R. P., 1976, A technique for assessing postural discomfort. *Ergonomics*, **19**, 175–82.

Coury, B. G., and Drury, C. G., 1982, Optimum handle positions in a box-holding task. *Ergonomics*, **25**, 645–62.

Deeb, J. M., Drury, C. G., and Begbie, K. L., 1985, Handle positions in a holding task as a function of task height. *Ergonomics*, **28**, 747–63.

Drury, C. G., Law, C.-H., and Pawenski, C. S., 1982, A survey of industrial box handling, *Human Factors*, **24**, 553–65.

Manuscript received 6 November 1984.
Accepted 14 February 1985.