手把設計與抬舉能力

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摘要

本研究探討手把高度及抬舉範圍對抬舉能力之影響。本研究探討了三種手把高度（10 公分高、30 公分高、50 公分高）及三種抬舉範圍（地板至 50 公分高、地板至 75 公分高、地板至 100 公分高）。本研究發現手把高度、抬舉範圍及其交互作用顯著地影響抬舉能力。手把高度為 30 公分高時會產生最大的抬舉能力。抬舉能力會隨著抬舉範圍的增加而遞減。在手把高度為 30 公分高及抬舉範圍為地板至 50 公分高之組合下所得到的抬舉能力為最大。此外，當實驗參與者施展最大的抬舉能力時，抬舉時間會隨著手把高度的增加而下降且箱子的最大仰俯傾斜角會隨著抬舉範圍的上升而增加。

關鍵詞：能力、箱子、抬舉

Handle Design and Lifting Capability

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Abstract

This study investigated the effects of handle height and lifting range on lifting capability. Three handle heights (10 cm high, 30 cm high, and 50 cm high) and three lifting ranges (floor to 50 cm, floor to 75 cm, and floor to 100 cm) were examined in this study. This study showed that handle height, lifting range and their interaction significantly influenced human lifting capability. This study indicated that middle handle height (30 cm high) could maximize lifting capability among the three handle heights, while lifting capability decreased with lifting range. Participants utilizing middle handles in the low lifting range could maximize their lifting capabilities. In addition, total lifting time decreased with increasing handle height, and maximum box tilt angle during the lifting, while it increased with increasing lifting range when participants performed their maximum lifting capabilities.

Keywords: Capability, Box, Lifting

Received: Jul. 19, 2022; first revised: Nov. 4, 2022, second revised: Jan. 4, 2023, third revised: Feb.21, 2023; accepted: Mar. 2023.
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I. Introduction

Manual materials handling tasks are prevalent in our daily or occupational works (Rajesh 2016; Nogueira et al. 2018; Borgss et al. 2019). They often involve a great deal of static or dynamic effort. Such effort is associated with accidents or overexertion injuries in musculoskeletal structure while performing manual materials handling tasks. Musculoskeletal injuries arising from manual materials handling tasks in manufacturing or people’s daily environments are widespread worldwide. According to the literatures, a large proportion of the accidents which occur in industry involve the manual handling of goods (Bridger 1995). Manual materials handling tasks were easy to wear lumbar intervertebral discs or other musculoskeletal structures, and thus resulting in a large proportion of musculoskeletal complaints. Some studies have also demonstrated that manual materials handling tasks were a major risk factor for work-related musculoskeletal disorders especially in the lower back (Manchikanti 2000; Van Nieuwenhuyse et al. 2004; Anwer et al., 2021; Widanarko et al., 2012). Some studies have also demonstrated that manual materials handling tasks were risky for low back injury (Manchikanti 2000; Van Nieuwenhuyse et al. 2004). The main results of the low back or other musculoskeletal troubles were work disability, a burden of medical cost and lost days from work.

Manual lifting tasks refer to the activities that people elevate an object from a lower position to a higher position manually. Manual lifting tasks occupy a large proportion of manual materials handling tasks and are associated with far more back injuries than other types of manual materials handling tasks (Sanders & McCormick 1993). To alleviate such injuries, a substantial body of studies has used several approaches, including biomechanical, physiological, and psychophysical approaches, to examine the effects of various factors on lifting tasks (Jung & Jung 2010; Fox & Smith 2014; Pinder & Boocock 2014; Al-Ashaik et al. 2015; Drain et al. 2016; Labaj et al. 2019; Sangachin & Cavuoto 2016; Shahvarpour et al. 2018). Despite no approach can totally eliminate the risk of lifting tasks, proper lifting technique and ergonomically-designed lifting conditions are considered to be helpful to reduce the risk of lifting tasks. These measurements include, for examples, getting as close to the object as possible, no twisting of the body, reducing load weight or size, adding handles to the load, adjusting the work environment etc.

Do not force to lift an object that is above one’s own lifting capacity can reduce overexertion and the risk of lifting. Limiting the weight of the lifted object can prevent lifters from overexertion. Evaluating human lifting capability and designing the work demand accordingly is a approach to lessen the overexertion injuries in manual lifting. Hence, the knowledge of human lifting capability is very important in designing an acceptable weight of the lifting. However, there are a lot of factors affecting human lifting capability. The handle design is one example of such factors. For the past decades, a lot of scientific papers had demonstrated the importance of handles design in materials handling tasks. For instances, providing handles in box could improve the operator/box coupling (Rigby 1973), reduce dropping the box (Drury & Pizatella 1983), reduce energy expenditure (Garg & Saxena 1980; Mital & Ayoub 1981). In addition, Lee and Yeh (2015) showed that maximum acceptable weights of carrying of carrying with bar handles were significantly higher than that of carrying with groove handles. However, all these studies used small size boxes in their experiments. To our knowledge, the effects of handles design in big box on human lifting capability did not receive interest in such previous papers.

From the perspective of biomechancis, good handles design in big box can help to avoid worker’s awkward posture and increase the worker’s capability. Experimental approach is widely used to evaluate the strains of and acceptable capabilities of the body in works. The basic hypothesis of this study was that handle height and lifting range were influential factors to human lifting capacity when lifting a big box. The main purpose of this study was to design an experiment to investigate the effects of handle height and lifting range on lifting capacity in the tasks of lifting big box. The second purpose was to observe the total lifting time and maximum box tilt angle during the lifting.

II. Method

1. Participants

Seventeen young and healthy males participated in this experiment. The mean (SD) age was 20.6(1.3) years, mean (SD) body weight was 64.0(10.0) kg, and mean (SD) height was 172.7(3.1) cm. All participants signed informed consent before experiment.

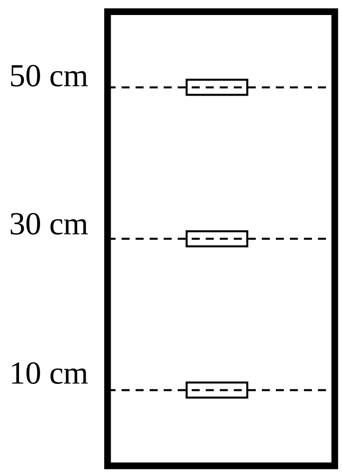
2. Experimental design

The independent variables of this study were handle height and lifting range. This experiment examined three handle heights and three lifting ranges. The three handle heights were low handles (10 cm), middle handles (30 cm), and high handles (50 cm). The three lifting ranges were floor to 50 cm high table, floor to 75 cm high table, and floor to 100 cm high table. The dependent variable of this study was lifting capability. The lifting capability was the maximum weight of the box that the participant was able to lift. In addition, this study also measured the total lifting time and maximum box tilt angle (maximum downward or upward pitch angle) during the lifting. The puropse to observe maximum box tilt angle was that it often resulted in load slide inside the box and thus body instability if the load could not be fastened in the lifting process.

3. Instruments

The instruments of this study were a big lifting box and a gyroscope. This study selected a light cardboard box (2.5 kg in weight) as lifting box in experiments. The dimension of this cardboard box was 50 cm long, 30 cm wide, and 60 cm high. The box provided low, middle, and high handles. The handles were 9 cm long and 3 cm high. These handles were centered at the width sides of the box. Figure 1 illustrates the handles of the box. A gyroscope (Xsens Technologies) was fixed on the top of southwestern corner of the box for measuring the total lifting time and maximum box tilt angle in the lifting. The sampling rate of the gyroscope signals was set at a rate of 100 Hz via computer software.

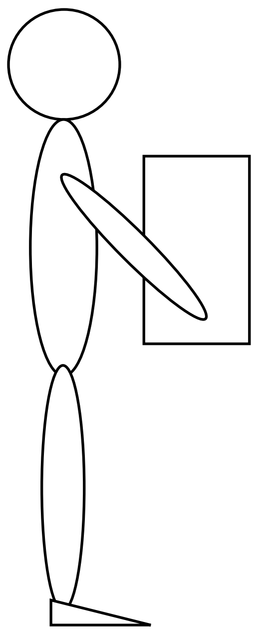
Figure 1.
Schematic figure of the saggital view of the box. Three pairs of cutout handles are designed in this box. Dash lines indicate the low (10 cm), middle (30 cm) and high (50 cm) handle heights, respectively.



4. Experimental procedure

Each participant was explained the procedures of this experiment thoroughly before the experiment. Each participant was asked to warm up himself before formal experiments. In formal experiments, each participant was asked to randomly perform 9 (3 handle heights × 3 lifting ranges) experimental conditions. For each experimental condition, the lifting box was randomly assigned an initial weight with iron shots. These iron shots were centered at the box (30 cm high of the box). Then, each of the participants was asked to perform all the nine experimental conditions using freestyle lifting technique. If the lifting weight was below the participant's capability and the participant succeeded the lifting, he was encouraged to add the iron shots inside the box without overexerting himself in the next try. After adding the iron shots, he tried the lifting task again. The above procedure repeated until the participant finally determined his own maximum weight for the lifting task. Figure 2 illustrates the schematic experimental condition for the participant and the box. The participant was provided approximately 5-minute rest between two consecutive progressive trials to avoid the participant fatigue during the lifting tasks.

Figure 2.
Schematic figure of the experimental condition for the participant and the box.



III. Results

All the data of dependent variables collected in this study were analyzed by standard statistical methods. Firstly, analysis of variance (ANOVA) was used to examine the effect of independent and possible interaction variables on dependent variables. For those independent or interaction variables that confirmed to have significant effect (α=0.05) on dependent variables, Duncan's multiple range test or interaction analysis was further applied to the data for post hoc comparison.

Table 1 shows the mean(SD) lifting capabilities of the participants. Table 1 indicates that participants could maximize their lifting capabilities with middle handle height. In addition, lifting capability decreased with lifting range. The ANOVA results of the lifting capabilities were shown in Table 2. Table 2 indicates that handle height and lifting range significantly influenced participants lifting capabilities. Additionally, the interaction of handle height and lifting range also significantly influenced participants lifting capabilities. Duncan's multiple range tests were further adopted the test the differences among the levels of significant factors found in ANOVA. They demonstrated that the lifting capabilities among the three handle heights and among the three lifting ranges differed significantly from one another ($p < 0.05$). Figure 3 shows the results of lifting capacities in all nine handle height and lifting range combinations. Figure 3 shows that the effect of lifting range on lifting capacity decreased in low handle height condition as compared with that in middle or high handle height condition. Table 3 shows the resulting results of total lifting times associated with the lifting capabilities. Table 4 shows the resulting results of maximum box tilt angles associated with the lifting capabilities. Table 3 shows that total lifting time decreased with increasing handle height. In addition, Table 4 shows maximum box tilt angle increased with increasing lifting range.

Table 1
The means(SD) of lifting capability (kg)

Variable	**Lifting range**		
Handle height	**Floor to 50 cm**	**Floor to 75 cm**	**Floor to 100 cm**
Low	38.7 (5.5)	34.7 (5.8)	29.0 (4.6)
Middle	46.8 (6.6)	40.9 (5.5)	33.3 (4.8)
High	41.9 (5.1)	34.8 (4.5)	28.3 (4.8)

Table 2
The ANOVA results for lifting capacity

Variable	**Lifting capacity**		
Source	**DF**	**F value**	**P > F**
Participants	16	66.35	<0.0001
Handle height	2	168.74	<0.0001
Lifting range	2	570.47	<0.0001
Handle height × Lifting range	4	6.76	0.0001
Error	128		

Table 3
The means(SD) of total lifting times (s)

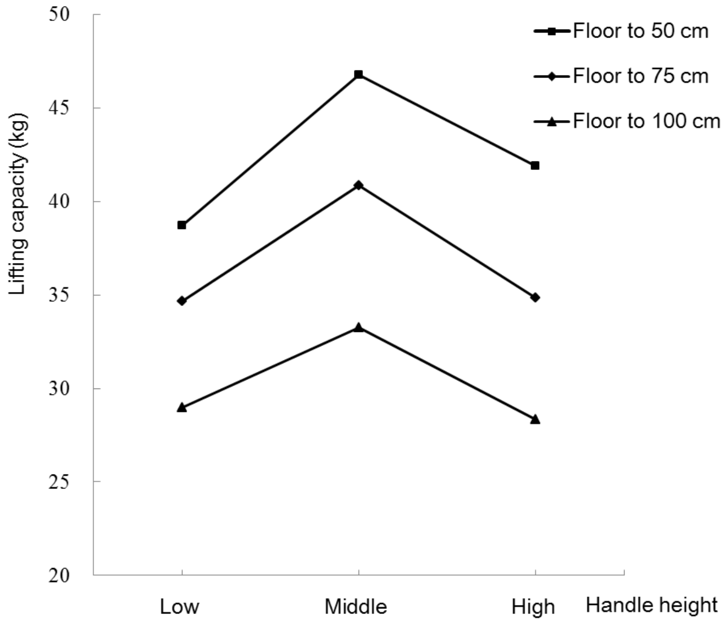
Variable	**Lifting range**		
Handle height	**Floor to 50 cm**	**Floor to 75 cm**	**Floor to 100 cm**
Low	2.09 (0.31)	2.30 (0.40)	2.23 (0.37)
Middle	1.87 (0.35)	2.06 (0.49)	1.98 (0.28)
High	1.68 (0.51)	1.61 (0.22)	1.84 (0.29)

Table 4
The means(SD) of maximum box tilt angle (degrees)

Variable	**Lifting range**		
Handle height	**Floor to 50 cm**	**Floor to 75 cm**	**Floor to 100 cm**
Low	12.8 (3.8)	18.3 (5.8)	24.4 (9.2)
Middle	13.8 (6.3)	16.9 (6.5)	26.2 (7.6)
High	11.1 (4.4)	14.6 (4.5)	17.6 (6.5)

Figure 3.

The results of lifting capacities in all nine handle height and lifting range combinations



IV. Discussion

Handles are necessary in box design. Suitable and comfortable handles could enhance our gripping and exerting forces in handling a box. The features of suitable and comfortable handles include their size, angle, shape, position, height… and so on. This study demonstrated that handle height significantly affected lifting capability. The greatest lifting capability was associated with middle handle height regardless of the three lifting ranges in this study. The lifting capabilities, averaged across all three lifting ranges, for low, middle, and high handle heights were 34.1 kg, 40.3 kg, and 35.0 kg, respectively. In this study, we found that middle handle height increased the participants' lifting capabilities by 18 % and 15 % as compared with low handle height and high handle height, respectively. This study attributed these findingse to the factors of hands position in the lifting and the compatibility between handles and load's center of gravity (COG). First, either low initial hands position (low handle height) or high final hands position (high handle height) limited the utilization and cooperation of muscles during lifting. Second, either low handles or high handles resulted in a bad compatibility between handle height and load's COG. Both results resulted in the decrease of participants lifting capabilities. On the contrary, the benefit of middle handles was that the load's COG (loacated at the center of box) was close to the handles providing the best compatibility between handles and load's COG. A good compatibility between handles and load's COG helped lifters to control and move the box due to better hand force application.

This study also observed total lifting time and maximum box tilt angle for a lifting, although they were not the dependent variables in this study. Since they were not the dependent variables in this study, this study could not analyze the effects of handle height and lifting range on total lifting time and maximum box tilt angle in ANOVA. It should be boted that both total lifting time and maximum box tilt angle were also affected by lifting weight (i.e lifting capability in this study). In addition, the box tilt angle observed was not equal to wrist deviation angle during the lifting process. Hence, this study could not compare the musculoskeletal strains across the handle heights or lifting ranges by observing total lifting time or maximum box tilt angle due to different lifting weights associated with them. This study only provided the results of total lifting times and maximum box tilt angles for maximum lifting capabilities. Overall, this study showed that middle handle height would increase lifting capability. It did not decrease total lifting time or maximum box tilt angle. In addition, total lifting time decreased with increasing handle height.

Large lifting range requires greater muscular efforts, and thus would limit participants lifting capabilities. The results of this study demonstrated that lifting range significantly affected lifting capability. Lifting capability decreased with lifting range regardless of the three handle heights. The lifting capabilities, averaged across three handle heights, for floor to 50 cm, floor to 75 cm, and floor to 100 cm lifting ranges were 42.5 kg, 36.8 kg, and 30.2 kg, respectively. In addition, lifting capability decreased by 14 % and 29 % as the lifting range increased from floor to 50 cm to 75 cm and to 100 cm, respectively. This study attributed the decrease of lifting capability to the strength capability of the responsible muscles utilized in lifting. In general, lifting tasks required the strength involvements of hands, arms, shoulders, trunk, and legs. However, the individual contributions of hands, arms, shoulders, trunk, and legs strengths among different lifting ranges differed, and thus affected the lifting capability. Lifting a box to a higher position required greater involvement of the upper extremity strength since the lifters should raise their hands. For example, lifters should raise their hands over 150 cm high in the lifting range of floor to 100 cm when using high handles. This posture was adverse to the strength exertions of hands, arms, and shoulders, and thus limited lifting capability. Overall, the result of this study showed that high lifting range resulted in low lifting capability and also accompanied by great maximum box tilt angle. Hence, practitioners should be advised to avoid high lifting range tasks that requiring heavy workloads.

Exerting one’s own lifting capacity efficiently and limiting the weight of the lifted object below one’s lifting capacity can prevent lifters from overexertion injuries. Our results showed that middle (30 cm) high handles was better for increasing lifting capabilities in the test settings of this experiment. The results of this study can guide practitioners to design the handles height in similar lifting tasks to increase lifters capabilities and reduce overexertion injuries. Finally, it should be emphasized that several task-related factors can also affect the lifting capabilities of this study, and the test settings of this experiment constitute limitations of this study. Hence, the generalization of the results can only be applied to the test settings similar to this study.

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