Human's Weight Perception from Container Handles

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Abstract. The objective of this study was to examine human's weight perception from container handles. The goal was to test the hypothesis that human's perception of weight is different if the container handle is not the same. Two experiments were conducted by using two plastic containers with same volume but different handles. Ten subjects between the ages of 18 and 20 yrs participated in this experiment. A set of weights was made from plastic containers filled with sandbags. The containers weighed between 1 and 10 kg with an increment of 1kg resulting in ten variable weights. The subjects were required to lift two weights in both the left and right arms simultaneously and compared the weight in the right hand (variable weight) to the one in the left hand (constant weight) and rated it on the CR-10 scale. The subjects were tested, before and after training, on the use of Borg's CR-10 scale. The results showed that there was no significant difference for human's weight perception between two types of handles. The subjects could only roughly distinguish two classes of weight :“light” and “heavy.” The boundary of light and heavy was approximately 5 kg. The main effect of gender on weight perception was significant, the weights perceived for females were significantly more than that for males. The weight perception values for both male and female subjects were less than the actual CR-10 values.

Keywords: Container handles; Perception of weight; Borg's CR-10 scale

1. INTRODUCTION

Weight perception is common and necessary for manual material handling operations, such as lifting, lowering, pushing, pulling objects. People perceive the weight of an object when lifting, holding, and using it. As early as 1834, Weber noted that a perceiver must lift an object in order to obtain an accurate perception of its weight—perception required action (Weber, E. H., 1978). As a part of the container, people grip and hold the handle when lifting an object. Therefore, it was significant to conduct a research on human's weight perception from container handles.

Scholars have conducted research on factors affecting of weight perception, such as size or color of object, muscle condition of subjects, lifting style, and etc. Scholars (Luczak and Ge, 1989; Karwowski, 1991; Yang et al., 1998; Wu and Chang, 2012; Dijker, 2014) conducted individual lifting and investigated interrelationships between the perceived heaviness and the cognitive concepts of load heaviness of the different combinations of object size and mass in manual lifting tasks. Deeb (1999) investigated muscular fatigue and its effects on weight perception. Huang (2014) carried out a research on psychological effect of color in weight perception. Amazeen (2011) conducted a research on lifting style and examined its effects on weight perception. Cui and Sun (2009) investigated human's weight perception from auditory and visual displays. However, previous study have shown that increases in research on factors analysis of weight perception are required and there is inadequate research dealing with container handles’ effects on weight perception.

People may be exposed to different types of container handles daily. Container handles were generally made of plastic, sponge, wood or iron, with shape or not. Normally, the size of container handles were consistent with the human hand. From the perspective of biomechanics, the difficulty of handling the object of the same weight was the same, considering the container handle. But actually, it was not clear why silicone handle felt lighter in the perception of the same quality than the plastic handle and why undee handle felt lighter than the stick-shaped handle etc. Also, with different size of container handle, the weight perception was different of the same weight. It seemed to be a perception effect, which was the so-called “weight illusion”. Therefore, objective measurements of physical stress, such as measured by the physical laboratory tests, may not present the perception of physical stress.

The objective of this study was to explore human's weight perception from container handles. The goal was to test the hypothesis that there was a relationship between subjective and objective measurements of physical stress.

2. METHOD

2.1 Subjects

Ten (5 males and 5 females) undergraduate students between 18 and 20 yrs participated in this experiment as human subjects. The subjects had no regular physical activity. All subjects were right-handed without history of musculoskeletal disorders.

2.2 Material

The material consisted of four lidded plastic buckets (two with handle A and two with handle B, capacity=10 litre, mass=512g) as containers, stopwatch, WeiHeng® portable electronic scale weight calculator. Borg's CR-10 scale (1982, see Table 1) was used in this study. Handle A was made of plastic whereas handle B was made of silica gel (width=8.5cm, length=2cm). A set of weights was made from plastic buckets filled with sandbags. The sandbags were created with a transparent plastic bag filled with sands of the same mass (1kg, except one sandbag of 488g to sum up the container mass of 512g). Based on the physical handling weight limit prescribed by the State of China (see Table 2), the plastic buckets weighed between 1 and 10 kg with an increment of 1kg (20%) resulting in ten (10) weights. As a proportion of the dimensions of the constant weight (5kg), the plastic bucket ranged from 20% to 200% of the constant weight of 5 kg.

Table 1: Borg's category-ratio scale (CR-10)

Number	Description
(.)	Maximal
10	Extremely strong (almost max)
9	
8	
7	Very strong
6	
5	Strong (heavy)
4	
3	Moderate
2	Weak (light)
1	Very weak
0.5	Extremely weak (just noticeable)
0	Nothing at all

2.3 Procedure

In waiting room, the subjects filled in the basic information sheet, read the instructions, signed a consent form and were introduced to the materials and the CR-10 scale. Upon entering the experimental room, the subject was instructed to stand on a specified test point. Prior to actual testing, each subject was instructed to use the left and right arms only. Throughout the study, subjects were presented with two weights and instructed to lift them with both arms simultaneously about 30 cm on the floor and hold them for five seconds. The left arm always lifted the constant weight (5kg) whereas the right arm always lifted variable weights (from 1kg to 10kg). After lifting, and during holding the weights, subjects were instructed to compare the variable weight (right arm) against the constant weight (left arm) and rate the variable weight using the CR-10 scale. The subjects were not informed about the actual weights they lifted. The procedure consisted of two experiments.

Table 2: Physical handling weight limit prescribed by the State of China

Gender	Category	Unit	Handling methods		
			Lift	Carry	Push or pull
Male	Single weight	Kg	15	50	300
	Daily weight	T	18	20	30
Female	Single weight	Kg	10	20	200
	Daily weight	T	8	10	16

Source: GB 12330-90 in China.

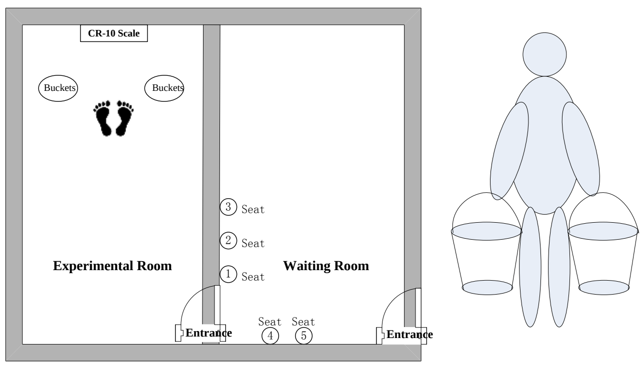

Figure 1: Layout of the experiment and lifting posture

2.3.1 Experiment I

Subjects were tested before and after being trained using the CR-10 scale with either handles A or B.

2.3.1.1 Testing before training

The subject was presented with two weights, with 5kg on left hand and 10 kg on right hand. After lifting the weights, the subject was instructed that they represent number ten (10) on the CR-10 scale. The same procedure was repeated for the lightest weight of 1 kg. However, here the subject lifted 1 kg with the right arm and 5 kg with the left arm. After lifting the weights simultaneously, the subject was told to compare and to feel the difference between the variable weight (1 kg) and the constant weight (5 kg). The subject was then told that the weight in the right hand, relative to the weight in the left hand, represents the number one (1) on the CR-10 scale. Again, this was repeated five times. After this initial introduction to the CR-10 scale, the subject compared the set of 10 variable weights against the constant weight of 5 kg and rated the variable weights using the CR-10 scale. This procedure was repeated five times. The ten variable weights were presented in a different random order for each of the five repetitions and for each subject.

2.3.1.2 Training

The subject was given the constant weight to hold with the left hand and the variable weights, in an ascending (20% to 200% of 5 kg) and descending (200% to 20% of 5 kg) order, in the right hand. The experimenter instructed the subject that each variable weight represents a certain number on the CR-10 scale. For example, the subject lifted a 2 kg, or 40% of 5 kg in the right hand and the constant weight of 5 kg in the left hand, and was instructed that the weight in the right hand represents the number two (2) on the CR-10 scale. This process was repeated three times for each of the ascending and descending orders. The second stage of training was to present the variable weights in a random order and instruct the subject what they represent on the CR-10 scale. This second stage was also repeated three times.

2.3.1.3 Testing after training

The subject was presented with the constant weight (5 kg) in the left hand and the variable weights (10% to 200% of the constant weight) in the right hand. The subject compared the variable weights against the constant weight and rated the variable weights on the CR-10 scale. This procedure was repeated five times. The variable weights were presented in a different random order for each of the five repetitions and for each subject.

2.3.2 Experiment II

With the plastic bucket handles changed from handle A to handle B, the same procedure was repeated for the plastic bucket with handle B.

3 RESULTS

3.1 Before and after training

The analysis of variance (see Table 3) demonstrated that the main effect of gender (G) was significant. Furthermore, the first order interactions of G×Tr was also significant. No second-order interaction will be discussed in this paper.

Table 3: Summary of analyses of variance for before and after training using handle A and handle B

Variance	Level of significance (*p<0.05)	F	p
Training (Tr)		1.257	0.262
Gender (G)	*	5.475	0.019
Handle (H)		0.569	0.450
G×H		1.10	0.294
G×Tr	*	4.88	0.027
H×Tr		0.79	0.375
G×H×Tr		0.20	0.654

The results showed that subjects were able to correlate well the percent weight to the appropriate CR-10 value especially after training (see Figure 2). The analysis using Newman-Keuls test on training revealed that the average CR-10 value of 5.34 for after training was significantly higher than that of 4.99 for before training. Indeed, the average CR-10 value for after training was very close to the average CR-10 scale value of 5.5.

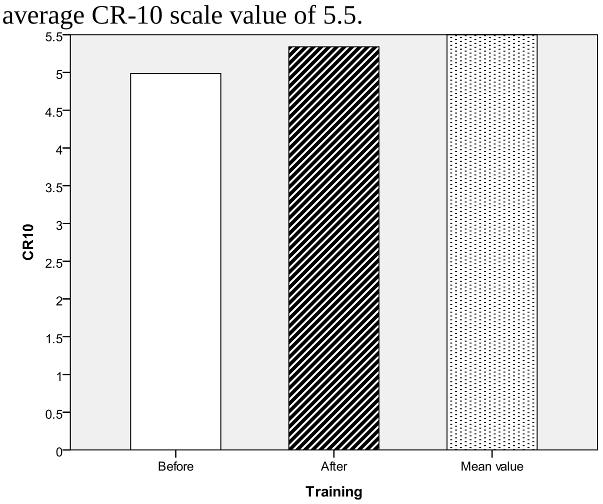

Figure 2: Mean CR10 values as a function of training

The G × Tr interaction (see Figure 3) showed the mean CR-10 values for female and male, training or not. The results showed again that male were able to correlate well the various weights to the appropriate CR-10 value especially after training, but female were not. The Newman-Keuls test results revealed that the means for before and after training for male were respectively 4.88 and 5.34. However, the means for before and after training for female were respectively 5.50 and 5.35.

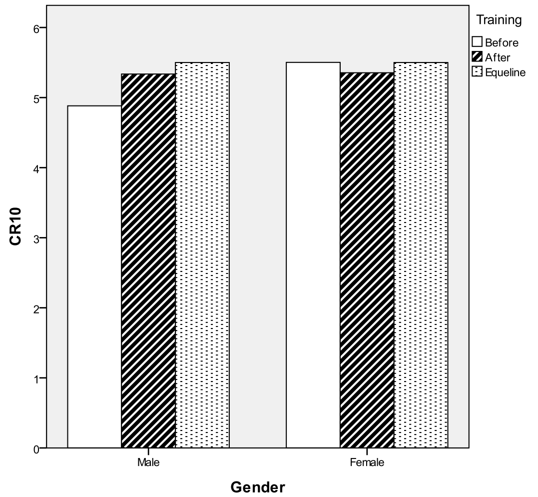

Figure 3: Mean CR-10 values for training and gender

The G × P interaction (see Figure 4) showed the mean CR-10 values for female and male, across all percent weights tested, further substantiates that the subjects' perception of the weights coincided with the CR-10 scale values. Indeed, the female line is very close to the line of equality. The correlation analysis results showed that the correlation coefficient for female was 0.93 whereas 0.83 for male (α=0.01, p=0.00). However, the female line was consistent well with the equality line for the weight from 1kg to 7kg but not for the weight from 8 kg to 10 kg.

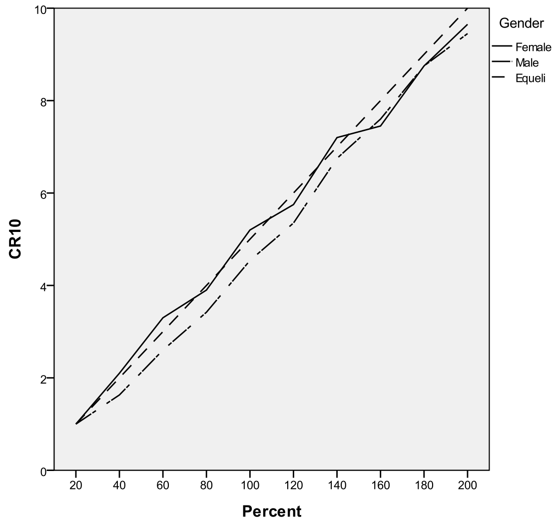

Figure 4: Mean CR-10 values for gender and percent interaction

3.2 Various weight with handles

The mean CR-10 values of handle A for gender (see Table 4) showed that the majority of the weight perception was inaccurate, either for male or for female, except for the weight of 1kg, 7kg and 8kg (p>0.05). And the weight perception of females was consistent with that of males in the weight perception of 1kg, 2kg 5kg and 8kg, but not for the rest. However, the results further substantiated that the boundary between light level and heavy level was about the CR-10 value of 5, which indicated 5kg (see Figure 5), and the subjective perception values begun to be consistent well with the objective value starting the weight of 7kg.

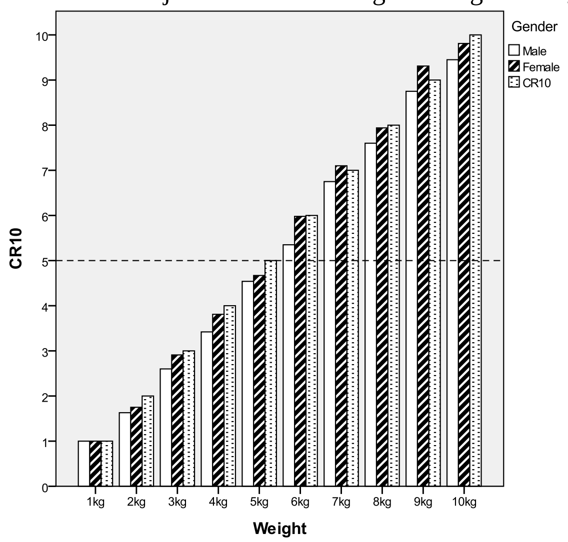

Figure5: Mean CR-10 values for gender from handleA

The mean CR-10 values of handle B for gender (see Table 5) showed that the majority of the weight perception was inaccurate as handle A, either for males or for females, except for the weight of 1kg, 7kg, 8kg and 9kg ($p>0.05$). And the weight perception of female was consistent well with that of males in the weight perception of 1kg, 2kg, 3kg, 5kg and 10kg, but not for the rest. However, the results also further substantiated that the boundary between light level and heavy level for handle B was about the CR-10 value of 5 (see Figure 6), which corresponded to 5kg. The subjective perception values began to be consistent with the objective values when the weight was 7kg or higher.

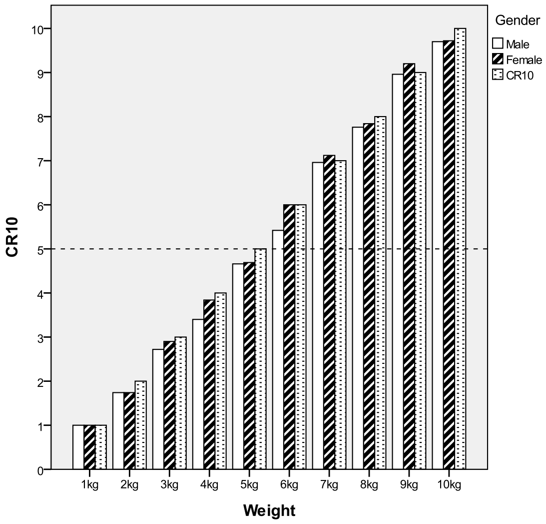

Figure 6: Mean CR-10 values for gender from handle B

4 DISCUSSION

The results of 3.1 showed that gender (G) had a significant effect on human's weight perception from container handles. The CR-10 values perceived by males seemed to be less than that by females, for the equivalent weight to be perceived. The most likely explanation for the results of this study was the difference of the maximum acceptable lifting force between females and males. Due to the difference of physiological structure, males generally could lift heavier weight than females. Therefore, the female subjects perceived the equivalent weight to be more than the actual values, whereas, the male subjects perceived the equivalent weight to be less than the actual values.

However, male subjects were able to correlate the various weights to the appropriate CR-10 values especially after training. The means of males for after training were 5.34 whereas 4.88 for before training. The training sessions were necessary for male subjects. The means of females for after training were 5.35 whereas 5.50 for before training. The training sessions were not that necessary for female subjects than male subjects. Anyway, training could be a means to improve the weight perception accuracy for males, to reduce the risk of underestimating the various weights.

The results showed that the majority of the weight perception was inaccurate across the male and female subjects, either for the plastic handle or silica gel handles. Humans could roughly distinguished light from heavy at the weight value of 5 kg. However, the perceived CR-10 values were consistent with the objective value when the weight was 7 kg or higher, especially for handle B. Actually, in terms of material, the most significant difference between plastic and silicone handles was resilience, which referred to the ability of restitution after stretching. Generally, plastic handles were stiff and had no resilience, but silicone handles were soft and had excellent resilience. In human handling task, silicone container handles could adjust itself to the hands of subjects whereas plastic container handles could not. Logically speaking, the weight perception for handle B should be less than that for handle A. However, since the resilience of handle B accounting for a small proportion of the total lifting force, there was no significant difference between plastic and silicone handles.

With inadequate researches in the field and limited by experimental conditions, future studies are required to expl ore information on weight perception under experimental c onditions other than the current study.

Table 4: Mean CR-10 values for gender from handle A

Weight	1kg	2kg	3kg	4kg	5kg	6kg	7kg	8kg	9kg	10kg
CR10	1^{a}	2^{b}	3^{b}	4^{b}	5^{b}	6^{b}	7^{b}	8^{b}	9^{ab}	10^{b}
Male	1^{a}	1.63^{a}	2.60^{a}	3.42^{a}	4.54^{a}	5.35^{a}	6.75^{a}	7.60^{a}	8.75^{a}	9.45^{a}
Female	1^{a}	1.75^{a}	2.91^{b}	3.81^{b}	4.67^{a}	5.98^{b}	7.10^{c}	7.94^{ab}	9.31^{b}	9.81^{b}
p	1	0.00^{**}	0.001^{**}	0.00^{**}	0.02^{*}	0.00^{**}	0.143	0.054	0.00^{**}	0.00^{**}

*$p<0.05$, **$p<0.01$, a, b, c referred to ascending order of Duncan multivariate analysis.

Table 5: Mean CR-10 values for gender from handle B

Weight	1kg	2kg	3kg	4kg	5kg	6kg	7kg	8kg	9kg	10kg
CR10	1^{a}	2^{b}	3^{b}	4^{b}	5^{b}	6^{b}	7^{b}	8^{c}	9^{b}	10^{b}
Male	1^{a}	1.74^{a}	2.72^{a}	3.4^{a}	4.66^{a}	5.42^{a}	6.96^{a}	7.76^{a}	8.96^{a}	9.70^{a}
Female	1^{a}	1.74^{a}	2.90^{ab}	3.84^{b}	4.69^{a}	6.00^{b}	7.12^{c}	7.84^{b}	9.20^{c}	9.72^{a}
p	1	0.003^{**}	0.039^{*}	0.00^{**}	0.002^{**}	0.00^{**}	0.653	0.426	0.238	0.006^{**}

$^{*}p<0.05$, $^{**}p<0.01$, a, b, c referred to ascending order of Duncan multivariate analysis.

5 CONCLUSIONS

No significant difference was found for human’s weight perception from plastic handles and silica gel handles. The main effects of gender and training were significant. The weights perceived for females were significantly higher than that for male. For both males and females, the weight perception values were less than the actual CR-10 values. The results showed that underestimating the actual weight may be one of the reasons for musculoskeletal disorders from manual material handling operations in industry. In order to enhance human’s weight perception to reduce this kind of injury, replacing the handle is invalid. Whereas, the training sessions was feasible. Reinforcing weight perception training was suggested for enterprises related to manual material lifting operations, to improve weight perception accuracy, especially for male staff.

In addition, the boundary between light and heavywas about 5 kg. The perceived mean CR-10 values began to be consistent with the objective values starting a weight of 7 kg for both handles. That was to say, humans could hardly distinguish from 1kg to 5 kg, and could hardly perceived the weight from 1kg to 7kg, which could provide a reference to training sessions.

The deficiency of this paper possibly lay in the involved limited number of sample (5 male and 5 female) or the limited types of container handles (plastic handles and silica gel handles). It was hoped that these problems could be explored by researchers who are interested in the field.

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