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Subjective Perception of Load Heaviness

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Subjective Perception of Load Heaviness

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This study examined human subjective perception of load heaviness. Forty-two (3 boxes × 14 weights) and 27 (3 boxes × 9 weights) experimental conditions were randomly presented to male and female participants, respectively. The results showed that the participants were not able to discriminate the effect of the box on perceived weight. The participants underestimated the weight for low weights and overestimated it for high weights. The females perceived a greater increase in weight than the males for the same increase in weight. The participants' linguistic term for perceived weight was positively correlated to the magnitude of weight. Approximately 50% of the males perceived a weight of 20 kg or over as risky, *while ~60% of the females perceived a weight of 14 kg or over as* risky. *This study supposes that the gender difference in muscular capability is responsible for the effect of gender on the risk perception of weight.*

psychophysics   weight discrimination   sense of force

1. INTRODUCTION

Perceptual ability is indispensable for human to explore the world. The use of human perceptual ability to discriminate weights and to assess physical work has a long history in psychophysical experiments. In 1834, German physiologist Ernst Weber postulated that the amount of just noticeable difference between a stimulus weight and a standard weight increased linearly with the size of the standard weight. The fraction of the just noticeable difference weight divided by the standard weight is known as the Weber fraction. The Weber fraction in discriminating weights ranges from .020 to .088 for different standard weights [1].

From 1967 on, human perceptual ability to discriminate weights has also been extensively used in the psychophysical approach to determining the maximum acceptable weight of load for manual materials handling tasks [2]. The psychophysical approach to determining the maximum acceptable weight of load requires participants to control the weight handled over a period of time, imagine working on the incentive basis and adjust the weight up to the maximum level without straining themselves or becoming unusually tired, weak, overheated, or out-of-breath. The psychophysical approach to determining the maximum acceptable weight of load is based on the assumption that workers are able to indicate with some accuracy the highest workload which is tolerable to them and the workloads accepted by workers are below the loads leading to manual materials handling injuries [3].

The functional relationship between human perceived magnitude and physical stimulus intensity is not linear. Stevens showed that the psychophysical functional relationship between perceived magnitude and physical stimulus intensity followed a power function of $\Psi = k\ \Phi^n$, where Ψ = perceived magnitude; Φ = physical stimulus intensity; k, n = parameters of the type of physical stimulus being scaled [4]. Much empirical evidence showed that perceived magnitude was a positively accelerated function of physical force ($n > 1$). The exponent of the psychophysical power function reported from a number of psychophysical experiments ranged from 0.8 to 2.0 when subjectively scaling physical forces [5], when pooled it was ~1.6.

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Perceived magnitude of load heaviness plays an important role in people realizing the workload in daily lives and selecting the maximum acceptable weight of load in psychophysical experiments [6, 7, 8, 9, 10]. However, human perceptual ability in discriminating weights is severely impaired due to the power function of perceived magnitude to physical stimulus intensity. Moreover, muscular fatigue affects human perceptual ability to discriminate weights [11]. Concluding from the results of several psychophysical experiments [12, 13, 14], human perceptual ability also differs by gender, with female participants considered to be more realistic in selecting maximum acceptable weight of load. The aims of this study were three-fold. Firstly, to examine the effects of box and weight on human perceived weight; secondly, to examine the psychophysical function of physical weight to perceived weight; thirdly, to examine the human subjective linguistic term and risk perception of perceived weight.

2. METHOD

2.1. Participants

Twenty-three males and 17 females participated in this study. All participants were students recruited from a university campus. The mean (*SD*) age, body height and mass were, respectively, 21.3 (1.3) years, 173.2 (5.4) cm and 63.9 (7.7) kg for the male participants; and 21.2 (1.3) years, 159.3 (4.3) cm and 49.1 (3.9) kg for the female participants. No participants had a medical record of back pain. The participants gave their written consent to participate.

2.2. Experimental Design

A randomized complete block design with participants as blocks was used to examine the effects of box and weight on the participants' perceived weight, linguistic term and risk perception of perceived weight. Three hardboard boxes sized (length × width × height) 58 × 40 × 23 cm, 58 × 30 × 23 cm, and 42 × 40 × 23 cm, respectively, were compared. The boxes varied in length (42 and 58 cm, coronal plane) and width (30 and

40 cm, sagittal plane). Each box had a pair of rectangular holes (15 cm long and 5 cm high) cut out at the center of the box width sides 10 cm from the bottom of the box to serve as box handles. Fourteen weights were selected for the male participants. The weight (including the empty box) ranged from 2 to 28 kg, in increments of 2 kg. Nine weights were selected for the female participants. The weight (including the empty box) ranged from 2 to 18 kg, in increments of 2 kg. This design of different weight limits for the male and female participants was based on the consideration of the difference in physical capability between genders. The total number of experimental conditions was 42 (3 boxes × 14 weights) for the male and 27 (3 boxes × 9 weights) for the female participants. The dependent variables were perceived weight, linguistic term, and risk perception of perceived weight. In this study, Karwowski's seven levels of linguistic terms (*very light*, *light*, *less-than-medium*, *medium*, *more-than-medium*, *heavy*, and *extremely heavy*) were presented for the participants to categorize perceived weight [14]. The risk perception of perceived weight was the participant's subjective perception of the risk the perceived weight posed to their musculoskeletal system. Two levels of risk perception (*risky* and *nonrisky*) were presented to participants for reporting their risk perception of perceived weight.

2.3. Experimental Procedure

The participants were required to refrain from excessive exercise before the experiments. All participants wore comfortable work clothes and safety shoes. All the experimental conditions (box × weight combinations) were randomly presented to each participant. The weight was centered inside the box. The box was covered so the participants had no visual cues as to its weight. For each experimental condition, the participants were asked to lift the box from the floor to knuckle height using a free lifting technique. Upon completion of the lifting, the participants were asked to estimate the load weight (perceived weight) and verbally select a linguistic term and report their risk perception of perceived weight.

2.4. Data Analysis

Analysis of variance (ANOVA) was used to examine the effects of participant, box, weight, and box–weight interaction on perceived weight. Duncan's multiple range test was used for post hoc comparisons of the differences between means of the response variables; α = .05 was taken as the level of significance for all statistical tests. Linguistic term and risk perception of perceived weight were presented with percentages.

3. RESULTS

Table 1 summarizes the means (*SD*) of the participants' perceived weights. Table 2 shows ANOVA results for perceived weights. It shows that the effect of weight on perceived weight was significant ($p < .001$), while the effect of box on perceived weight was not significant ($p > .05$). Duncan's multiple range tests were further performed to determine the differences of perceived weights among levels of weights. Table 3 shows the results. Since the box did not significantly affect perceived weight, perceived weights of the three boxes were then averaged to depict the psychophysical relationships between perceived weight and physical weight. Figure 1 shows the relationships obeyed the power function.

Table 4 shows the percentages of the participants' linguistic terms for the weights. For the male participants, a weight of 6 kg or under was often categorized as *very light*, 8 kg was often categorized as *light*, 10–14 kg was often categorized as *medium*, 16–18 kg was often categorized as *more-than-medium*, 20–22 kg was often

TABLE 1. Means (*SD*) of Perceived Weight (kg)

Variable (Weight, kg)	Box					
	58 × 40 × 23 cm		58 × 30 × 23 cm		42 × 40 × 23 cm	
	Males	Females	Males	Females	Males	Females
2	0.5 (0.4)	0.4 (0.3)	0.7 (0.7)	0.5 (0.3)	0.6 (0.6)	0.6 (0.3)
4	1.5 (1.4)	1.7 (1.0)	1.4 (1.1)	1.5 (1.1)	2.1 (1.7)	1.7 (1.3)
6	2.8 (1.8)	2.9 (2.3)	3.4 (2.1)	3.3 (1.9)	3.3 (2.2)	2.7 (1.3)
8	5.2 (3.2)	4.9 (4.0)	4.8 (2.7)	5.6 (3.4)	4.5 (2.6)	4.7 (2.9)
10	5.5 (3.3)	7.0 (5.1)	6.8 (3.3)	7.3 (3.9)	6.8 (3.7)	7.6 (3.7)
12	7.8 (3.7)	10.2 (5.4)	8.2 (4.3)	9.2 (6.0)	9.1 (5.1)	10.8 (6.1)
14	9.4 (4.4)	14.3 (7.7)	10.7 (4.2)	11.6 (5.6)	11.8 (6.6)	15.0 (7.3)
16	14.5 (4.8)	18.7 (7.2)	13.5 (4.5)	17.5 (10.6)	14.0 (5.8)	19.4 (8.5)
18	16.2 (4.6)	21.2 (7.1)	16.0 (6.5)	21.2 (10.2)	15.9 (3.7)	22.9 (8.0)
20	19.7 (5.8)		17.9 (5.0)		20.1 (5.5)	
22	21.2 (5.6)		18.6 (5.3)		21.3 (5.5)	
24	24.2 (6.1)		21.9 (7.1)		24.1 (6.0)	
26	28.9 (6.9)		28.0 (6.7)		27.0 (7.0)	
28	33.3 (7.8)		30.2 (7.0)		31.0 (9.0)	

TABLE 2. Results of Analysis of Variance (ANOVA) for Perceived Weight

Source	Males					Females				
	df	*SS*	*MS*	*F*	*p > F*	*df*	*SS*	*MS*	*F*	*p > F*
Participant	22	5695.5	258.8	14.1	< .001	16	5103.5	318.9	17.8	< .001
Box	2	89.9	44.9	2.4	.086	2	37.1	18.5	1.0	.355
Weight	13	89173.3	6859.4	376.0	< .001	8	21909.3	2738.6	152.8	< .001
Box × weight	26	456.7	17.5	0.96	.518	16	161.6	10.1	0.56	.910
Error	902	16455.5	18.2			407	7293.4	17.9		
Corrected total	965	111871.1				449	34505.1			

Notes. Males: $R^2 = .853$; females: $R^2 = .789$.

TABLE 3. Results of Duncan's Multiple Range Tests for Perceived Weight (kg)

Variable (Weight, kg)	Males		Females	
	M (*SD*)	Grouping	*M* (*SD*)	Grouping
2	0.6 (0.6)	L	0.5 (0.3)	H
4	1.7 (1.4)	L	1.6 (1.1)	G H
6	3.1 (2.0)	K	3.0 (1.9)	G
8	4.8 (2.8)	J	5.1 (3.4)	F
10	6.3 (3.4)	I	7.3 (4.2)	E
12	8.4 (4.4)	H	10.1 (5.8)	D
14	10.6 (5.2)	G	13.7 (7.0)	C
16	14.0 (5.0)	F	18.5 (8.8)	B
18	16.0 (5.0)	E	21.7 (8.5)	A
20	19.2 (5.4)	D		
22	20.4 (5.5)	D		
24	23.4 (6.4)	C		
26	28.0 (6.8)	B		
28	31.5 (7.9)	A		

Notes. Means with the different letter in Grouping were significantly different ($p < .05$).
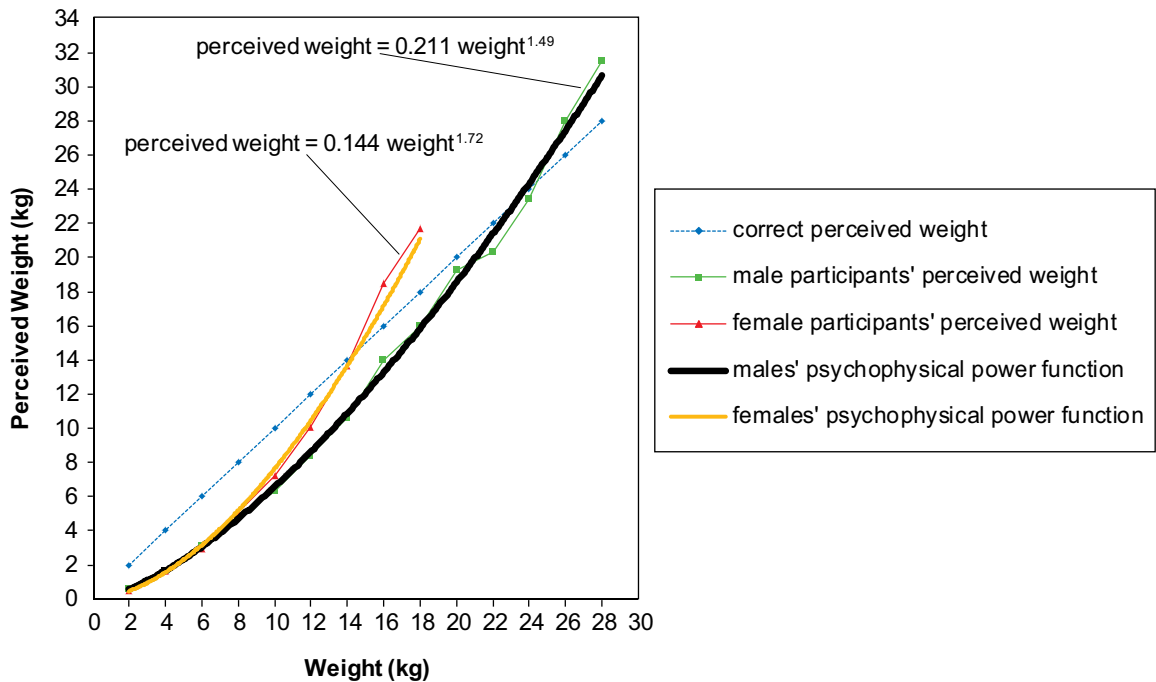

Figure 1. The psychophysical power function and the relationship between perceived and physical weight.

categorized as *heavy*, 24 kg or over was often categorized as *extremely heavy*. For the female participants, a weight of 6 kg or under was often categorized as *very light*, 8 kg was often categorized as *medium*, 10–12 kg was often categorized as *more-than-medium*, 14 kg or over was often categorized as *extremely heavy*.

Table 5 shows the participants' responses of *risky* perception for the weights; ~50% of the male participants perceived a weight of 20 kg or over as *risky*, while ~60% of the female participants perceived a weight of 14 kg or over as *risky*.

TABLE 4. Participants' Linguistic Terms for Weight (%)

Variable (Weight, kg)	Males							Females						
	VL	L	LTM	M	MTM	H	EH	VL	L	LTM	M	MTM	H	EH
2	88.4	11.6						100						
4	59.4	33.3	4.3	2.9				78.4	13.7	3.9	3.9			
6	44.9	24.6	11.6	14.5	4.3			45.1	31.4	13.7	9.8			
8	17.4	34.8	15.9	27.5	4.3			13.7	21.6	19.6	33.3	11.8		
10	7.2	18.8	7.2	43.5	17.4	4.3	1.4	2.0	11.8	5.9	33.3	41.2	5.9	
12		21.7	15.9	40.6	14.5	5.8	1.4		3.9		21.6	47.1	11.8	11.8
14	1.4	5.8	2.9	44.9	30.4	11.6	2.9		2.0	3.9	9.8	25.5	29.4	29.4
16		2.9	7.2	24.6	39.1	21.7	4.3			5.9	5.9	7.8	17.6	62.7
18			2.9	18.8	39.1	24.6	14.5				5.9	7.8	9.8	76.5
20			1.4	10.1	26.1	39.1	23.2							
22				7.2	15.9	39.1	37.7							
24				8.7	15.9	23.2	52.2							
26				2.9	4.3	24.6	68.1							
28				2.9	4.3	13.0	79.7							

Notes. VL = *very light*, L = *light*, LTM = *less-than-medium*, M = *medium*, MTH = *more-than-medium*, H = *heavy*, EH = *extremely heavy*.

TABLE 5. Participants' *Risky* Responses for Weight (%)

Weight (kg)	Males	Females
2	0	0
4	0	0
6	0	0
8	0	0
10	0	9.8
12	2.9	39.2
14	10.1	60.8
16	24.6	82.4
18	31.9	90.2
20	49.3	
22	56.5	
24	65.2	
26	75.4	
28	91.3	

4. DISCUSSION

Even though the box of 58 × 40 × 23 cm imposed greater shoulder strain than the box of 42 × 40 × 23 cm due to a longer moment arm to shoulder, or imposed greater low back strain than the box of 58 × 30 × 23 cm due to a longer moment arm to low back, this study showed that the participants were not able to discriminate the biome-chanical strains across the three boxes for the same weight. This result implies that people, without being aware, experience more bio-mechanical risk in the wider or longer box examined in this study. However, it should be noted that the nonsignificant effect of box on perceived weight might be attributed to the small differences in size among the boxes selected for this study. Further study is necessary to explore the effect of box on perceived weight across greater differences in box size.

Table 3 shows that the participants were able to discriminate the weight differences across most weights. Despite this, this study clearly showed that the participants underestimated the weight for low weights, while they overestimated the weight for high weights. This phenomenon obeyed the property of the power function between perceived weight and physical weight. The most accurately perceived weight was located at 14 kg for the female participants and at 24 kg for the male participants. The weight of 14 kg was categorized as either *heavy* or *very heavy* by most female participants (59%). The weight of 24 kg was categorized as either *heavy* or *very heavy* by most male participants (75%). The property of underestimating the magnitude of heavy or less heavy weights

provided some evidence on the overestimation of maximum acceptable weights revealed in some psychophysical experiments [12, 15].

The power function satisfactorily depicted the psychophysical relationship between perceived weight and physical weight. The exponents of the psychophysical power function were 1.49 and 1.72 for the male and female participants, respectively. These exponents were within the range of 0.8–2.0 reported in a number of psychophysical experiments when subjectively scaling physical forces [5]. Notably, the exponent of the females was greater than that of the males indicating that the females perceived a greater increase in weight than the males did for the same increase in weight. This result might be attributed to the weaker force capability of females than of males, and the females did not take unnecessary risks as the males did. It might also support the finding that females are more realistic than males in selecting maximum acceptable weight of load in a psychophysical study [14].

Table 4 shows that the participants' linguistic term for weight was positively correlated to the magnitude of weight. However, the participants often seemed to neglect the term *less-than-medium* when categorizing perceived weight. For example, most males categorized 8 kg as *light*; however, they categorized 10 kg as *medium*. The phenomenon was similar for females. Most females categorized 6 kg as *very light*; however, they categorized 8 kg as *medium*. The result revealed a linguistic gap between *light* and *medium*. Why participants did not use the term of *less-than-medium* when categorizing perceived weight is interesting. The psychophysical power function might provide an explanation. The positively accelerated psychophysical power function shows that the differential perceived weight for any two consecutive experimental weights increases with the weight magnitude. This implies the participants found it more difficult to discriminate the differences among light weights. Another possibility is that the participants might not be accustomed to using the term *less-than-medium* to describe perceived weight.

This study shows that males and females differ in the way they perceive risk posed by a given weight. This study explains this finding from the perspective of the gender difference in muscular capability. This study examined the effect of gender on the risk perception of weight by comparing weights perceived as *risky* by males and by females on the basis of a similar percentage of responses. For example, ~91% of the male participants perceived 28 kg as *risky* and 90% of the female participants perceived 18 kg as *risky*. The ratio of 18 to 28 kg is 64%. This ratio is close to the general rule of thumb that female muscular capability is approximately two thirds of male muscular capability [16]. Hence, this study supposes that the gender difference in muscular capability was responsible for the effect of gender on the risk perception of a given weight.

5. CONCLUSIONS

This study examined the effects of box and weight on perceived weight, the psychophysical function of weight to perceived weight, and the linguistic term and risk perception of participants for perceived weight. The main conclusions from this study were that (a) the participants underestimated the weight for low weights and overestimated the weight for high weights; (b) the female participants perceived a greater increase in weight than the males participants for the same increase in weight; (c) ~50% of the male participants perceived a weight of 20 kg or over as *risky*, while ~60% of the female participants perceived a weight of 14 kg or over as *risky*.

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