

Effect of One-side-shoulder Bag Holding with Different Weights on Center of Gravity Shaking during a Standing Posture in Young Women

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Abstract Center of gravity shaking (CGS) changes constantly during a standing posture and its variation increases depending on the disturbance stimulus. One-side-shoulder bag (OSB) holding with a heavy weight makes the standing posture unstable because it imposes burden on one side of the shoulder and/or lower back. It is assumed that the effect of OSB on CGS differs by bag weight and the habitual and non-habitual use of one shoulder. This study aimed to examine the effect of different weights and holding shoulders on CGS during OSB in a standing posture in 30 healthy young women aged 21-24 years. The experimental conditions were relative weight loads (0% [non-bag holding], 5%, 10%, and 15% of body mass [BM]) and bag holding shoulder (habitual and non-habitual). The participants maintained a Romberg posture (standing posture with feet closed) with eyes open for 1 minute on the measurement equipment in the above-mentioned eight conditions. The x-axis, y-axis, and total trajectory lengths and outer peripheral area were transmitted to a computer at a sampling rate of 20 Hz. The measurement order was randomized for the different weight loads and holding shoulders. Two measurements were obtained for each condition with a 1-min rest between measurements. The two measurements were then averaged. A two-way analysis of variance (ANOVA) showed that the x-axis, y-axis, and total trajectory lengths were significantly higher for weight loads of 10% BM and above. The outer peripheral area value was significantly lower for the habitual holding shoulder. The 10% and 15% BM weights had significantly higher outer peripheral area values compared with the 0% BM weight, and the 15% BM weight had significantly higher outer peripheral area values compared with the 5% and 10% BM weights. The x-axis, y-axis, and total trajectory lengths and outer peripheral area become greater as bag weight increases over 10% BM. OSB holding leads to a larger outer peripheral area in the non-habitual holding shoulder compared with the habitual holding shoulder in young women.

Keywords: humans, functional balance, body mass redistribution, stability, analysis of variance

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1. Introduction

The center of gravity position during a standing posture is determined by postural and skeletal muscle alignment [1,2]. Center of gravity shaking (CGS) during a standing posture depends on reflex control, based on afferent inputs from the visual, vestibular (semicircular duct), and somatosensory systems [3,4]. It is also influenced by factors such as fatigue, drinking, and aging [5,6,7,8]. If postural and skeletal muscle alignment conditions change due to fatigue or poor health, the center of gravity position is also thought to fluctuate.

The center of gravity sways constantly to maintain a stable standing posture, and its variation increases depending on the disturbance stimulus [9,10]. CGS in

humans mainly uses center of pressure [11,12], alongside sway variables, such as forward/backward, left/right, and total trajectory lengths; moving velocity; and area component [9]. Matsuda et al. [13] reported that a disturbance stimulus that imposes burden on the hip abductor influences the sway variation of the left/right direction compared with the forward/backward direction, which suggests that the affected CGS component (sway variable) differs depending on the type of disturbance stimulus. Based on these findings, we consider that the degree to which sway variables are affected depends on the magnitude and type of disturbance stimulus.

Another factor that may affect CGS is lateral dominance in the function of the upper limbs, which include the fingers and arms [14]. One of the causes for lateral dominance is the frequent use of one hand and arm [15]. Right-handed individuals find it easier to operate the

right than the left hand in tasks such as the pegboard test [16] and as the result, show better performance [15]. One-side-shoulder bag (OSB) holding also varies across individuals, where a bag is held habitually on either the right or left shoulder. Hill & Price [9] reported that OSB holding with a heavy weight leads to an unstable standing posture due to the burden imposed on one-side shoulder and/or lower back. Individuals that habitually hold a bag on the right shoulder maintain their postural stability by holding a bag with the right shoulder. Therefore, if they hold a bag on the left shoulder, it causes an unfamiliar feeling. Moreover, the one-side effect on CGS and related variables is considerable, especially if the bag is heavy. However, this problem has not been examined previously.

Taken together, we hypothesized that OSB holding affects CGS during a standing posture, and its effect will be larger with increasing weight (hypothesis 1). Furthermore, OSB holding on the non-habitual shoulder will have a larger one-side effect on CGS compared with OSB holding on the habitual shoulder (hypothesis 2).

This study aimed to examine the effects of different weights and holding shoulder (habitual and non-habitual shoulder) during OSB on CGS while in a standing posture.

2. Methods

2.1. Participants

Participants were 30 young women university students (aged 21-24 years; mean age = 22.4 years, standard deviation [SD] = 1.0 year; mean height = 156.7 cm, SD = 5.3 cm; mean weight = 51.0 kg, SD = 8.7 kg). The habitually used shoulder for OSB holding was confirmed using a questionnaire. Twenty-five participants used the right shoulder, and five participants used the left shoulder. The mean values for height and body mass (BM) were similar to Japanese normative values of the same age [17]. None of the participants reported previous wrist injuries or upper limb nerve damage, and all were in good health. Prior to participation, the purpose and procedure of the study were explained in detail to all participants, and all provided signed informed consent. The experimental protocol was approved by the Ethical Review Committee for Medical and Health Research Involving Human Subjects of Japanese Society of Test and Measurement in Health and Physical Education (approval number: 2018-001) and Kyoto Pharmaceutical University (approval number: 20-18-20). This study was conducted based on the Declaration of Helsinki of 1964 guidelines, as revised in 2013. None of the participants had undergone a CGS test previously.

2.2. Apparatus

The apparatus consisted of an instrument to measure center of gravity trajectory (TKK-5810; Takei, Tokyo, Japan) and a laptop computer. The center of gravity trajectory values were transmitted to a computer at a sampling rate of 20 Hz through a USB data output cable after A/D conversion. The CGS apparatus has been described in detail previously [18].

2.3. Measurement of Center of Gravity Shaking (CGS)

The experimental conditions were relative weight loads (0% [non-bag holding], 5%, 10%, and 15% of BM) and bag holding shoulder (habitual and non-habitual). The subjects maintained a Romberg posture (a standing posture with feet closed) with eyes open for 1 minute wearing socks on the CGS apparatus in the above-mentioned eight conditions. The measurement order was randomized for the different weight loads and holding shoulder. Once the subject was confirmed to be putting a long strap bag on one's shoulder and holding a standing posture based on the point of gaze, which was set at eye level, a measurement was taken. Two measurements were taken with a 1-min rest between measurements for eight conditions.

2.4. Variable Estimations

The following CGS variables were evaluated as described in a previous study [19]: x-axis trajectory length (distance in mm of CGS movement along the x-axis); y-axis trajectory length (distance in mm of CGS movement along the y-axis); total trajectory length (distance in mm of total distance of CGS movement); and outer peripheral area (internal area of the outer circumference of the CGS in mm²). They were transmitted to a computer at a sampling rate of 20 Hz. An average of the two trials in each condition for weight load and holding shoulder was used for analysis.

2.5. Statistical Analysis

Data were analyzed using SPSS version 23.0 for Windows software (SPSS Inc., Tokyo, Japan). Descriptive statistics were reported as mean \pm SD. A two-way analysis of variance (ANOVA) was used to examine significant differences between the different weight loads and holding shoulders for each estimate variable. For significant main effects, we used a multiple comparisons test using the Bonferroni method for pairwise comparisons. $p < 0.05$ was used for statistical significance.

3. Results

Figure 1 shows the means and SDs for each CGS variable for each weight load and holding shoulder. Table 1 shows the results of the two-way ANOVA for each CGS variable.

The two-way ANOVA did not reveal any significant interactions in any of the CGS variables (the x-axis, y-axis, total trajectory lengths, and outer peripheral area). Significant main effects were found for all trajectory length variables for the weight load factor: the 10% BM weight had higher values than the under 5% BM weight, and the 15% BM weight showed higher values than the under 10% BM weight. Significant main effects were found for outer peripheral area for both weight load and holding shoulder. The multiple comparisons test showed that for weight load, the 10% and 15% BM weight had higher values than the 0% BM weight, and the 15% BM

weight had higher values than the 5% and 10% BM weights. For holding shoulder, there were no significant

differences between the weight loads. The effect size (η^2) was considered small.

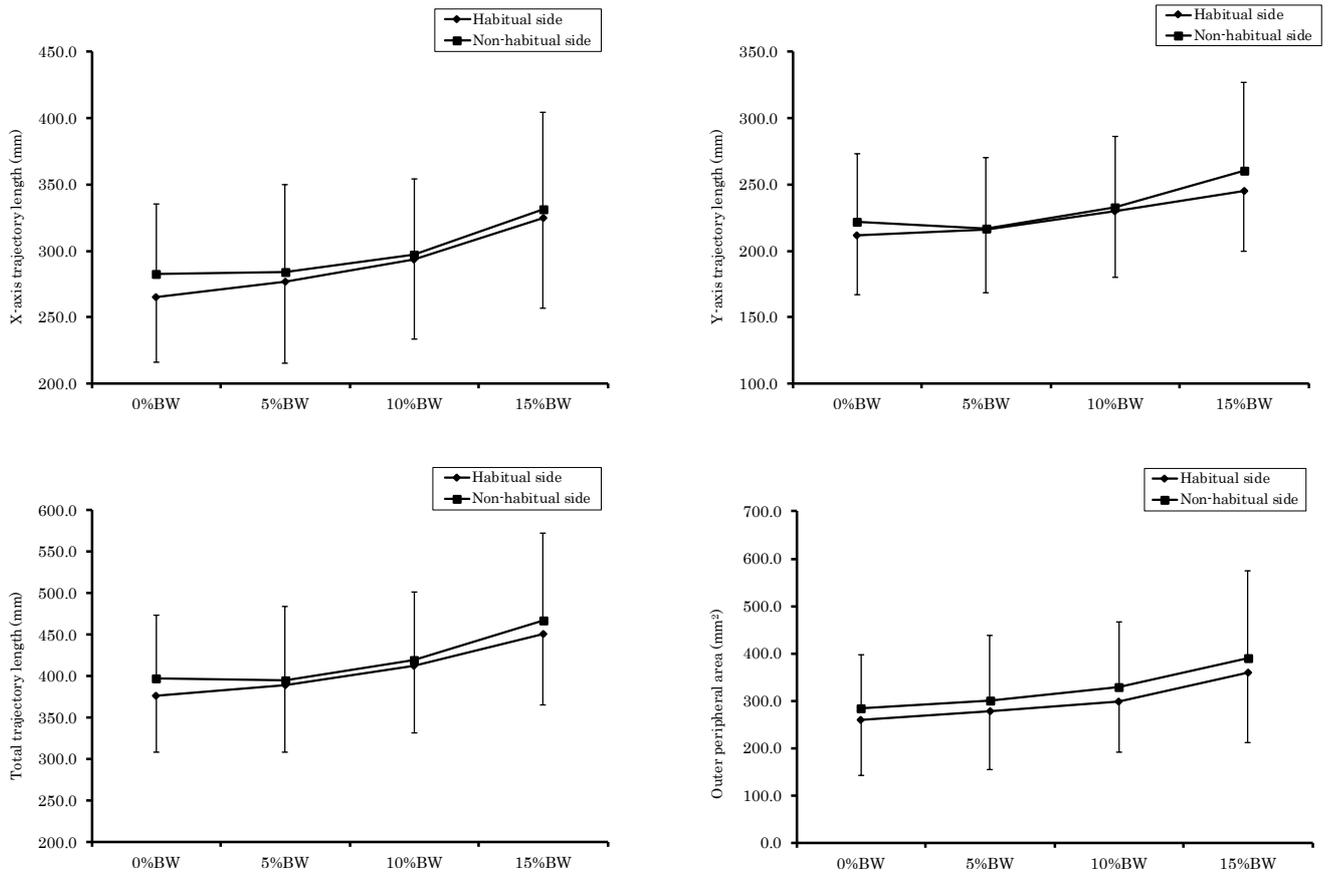


Figure 1. Means and standard deviations of each CGS variable according to weight load and holding shoulder factors

Table 1. The results of two-way analysis of variance for each CGS variable

Variables	Factor	df	F	p	partial η^2	Multiple-comparison test	
X-axis trajectory length	Shoulder	1	2.74	0.11	0.09		
	Error	29	(1575.37)				
	Weight	3	42.50	0.00	*	0.59	0%, 5%<10%<15%
	Error	87	(824.11)				
	Shoulder \times weight	3	0.88	0.45		0.03	
Y-axis trajectory length	Shoulder	1	2.54	0.12	0.08		
	Error	29	(1289.46)				
	Weight	3	28.41	0.00	*	0.50	0%, 5%<10%<15%
	Error	87	(824.11)				
	Shoulder \times weight	3	1.30	0.28		0.03	
Total trajectory length	Shoulder	1	3.42	0.08	0.11		
	Error	29	(2819.43)				
	Weight	3	46.66	0.00	*	0.62	0%, 5%<10%<15%
	Error	87	(1372.32)				
	Shoulder \times weight	3	0.89	0.45		0.03	
Outer peripheral area	Shoulder	1	4.38	0.05	*	0.13	Habitual side < Non-habitual side
	Error	29	(10228.55)				
	Weight	3	18.37	0.00	*	0.39	0% <10%, 15% 5%, 10%<15%
	Error	87	(6653.01)				
	Shoulder \times weight	3	0.05	0.99		0.00	
Error	87	(5592.63)					

note) CGS: Center of gravity shaking, *: p < 0.05.

4. Discussion

OSB holding with a heavy weight leads to an unstable standing posture due to the burden imposed on one-side shoulder and/or lower back [9]. If postural and skeletal muscle alignment conditions change because of a disturbance stimulus, there is a fluctuation in the center of gravity position, which is involved in afferent inputs from the visual, vestibular (semicircular duct), and somatosensory systems and its processing. This effect differs depending on the type of disturbance stimulus. Therefore, we consider that the differences in bag weight and holding shoulder will be reflected in the changes in CGS.

In this study, we hypothesized that OSB holding with a heavy bag will affect CGS while in a standing posture. Specifically, we expected CGS increase with increased bag weight (hypothesis 1). We examined the effect of different weights on CGS during a standing posture. Our results showed that there was no effect of weights below 5% BM on any of the measured variables. However, effects were observed for bag weight of 10% BM or heavier on all measures of trajectory length, which were larger for the 10% BM and 15% BM weights than in the 5% BM weight, and for the 15% BM weight than in the 10% BM weight. The outer peripheral area was larger for the 10% and 15% BM weights than in the 0% BM weight, and for the 15% BM weight than in the 5% and 10% BM weights. That is, it was clarified that the light weights under the 5% BM have no effect on the CGS, but the weights over the 10% BM influence the CGS. Hill & Price [9] also reported that weights under 5% BM had little effect on sway. The x-axis and y-axis trajectory lengths are variables that reflect left/right and forward/backward migratory distances, respectively. OSB holding of heavy weights not only affected left/right migratory distances but also the forward/backward migratory distances. We suggest that total trajectory length also showed large variation because both trajectory lengths increased. It has been previously demonstrated that CGS during a standing posture becomes larger with increasing load to one side of the body [9]. Our results suggest that regardless of the difference between habitual and non-habitual shoulders, a one-side shoulder load not only affects left/right sway but also forward/backward sway, and this effect becomes larger with increasing weight. We speculate that the strain (tone) of the lower limb becomes greater with increasing weight to maintain a stable posture, which influences CGS. Our results support our first hypothesis. Because OSB holding of weights heavier than 10% BM produces postural instability, more attention needs to be paid from the perspective of fall prevention.

We did not find any effect of holding shoulder on measures of trajectory length; however, outer peripheral area was smaller in the habitual shoulder compared with the non-habitual shoulder. We hypothesized that CGS values during a standing posture would be larger in the non-habitual shoulder than in the habitual shoulder (hypothesis 2). And we examined the effect of habitual and non-habitual OSB holding on CGS while in a standing posture. Dolcos et al. [20] and Roy et al. [21] examined the functional asymmetry of each part of the body and reported that the dominant side is superior to the non-dominant side. Demura et al. [14] reported that performance in motor tasks that require the skills of the

fingers and upper arms relates to laterality, where the dominant side is superior in motor control function. Because of the constant use of the one-side habitual shoulder as well as the dominant hand, in case of the one side light bag weight, individuals do not experience discomfort and can thus maintain stability in a standing posture, despite the burden imposed by the habitual shoulder on one side of the body. In our study, the distance variables were not affected. The outer peripheral area was larger for the non-habitual shoulder, but this difference was not large. As mentioned earlier, the total trajectory length, which is the migratory distance of gravity, increases if the x-axis and y-axis trajectory lengths become longer. Because the outer peripheral area corresponds to the internal area of the outer circumference of CGS [19], it is affected by variations in the left/right and forward/backward distances; however it primarily relates to the migratory scope. In the case of a small scope of left/right and forward/backward variation, the outer peripheral area is small, but the total trajectory length can be large because of repeated movements within the scope. Our results suggest that the change in holding shoulder influences the migratory scope of CGS, but the effect is not large. Therefore, our second hypothesis was supported for outer peripheral area only.

4.1. Future Directions

The present study used healthy young women as subjects. However, there have been reports that there are sex differences in CGS [5]. Because men are often taller and have superior lower leg strength [17], the effects of OSB holding of different weights on CGS while in a standing posture may differ from those in women. In addition, in middle-aged adults with inferior peripheral muscular responses to disturbance stimuli and balance ability, CGS during OSB holding of different weights in a standing posture may differ from that in young adults. A follow-up study will be needed to examine the effects in young men and middle-aged adults.

In conclusion, we found that in young women, the x-axis, y-axis, and total trajectory lengths and outer peripheral area become larger with a bag weight increase in 10% BM and above. The outer peripheral area was larger in the non-habitual holding shoulder compared with the habitual holding shoulder.

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Statement of Competing Interests

The authors have no competing interests.

References

- [1] Pascoe, D.D., Pascoe, D.E., Wang, Y.T., Shim, D.M., and Kim, C.K. "Influence of carrying book bags on gait cycle and posture of youths," *Ergonomics*, 40(6), 631-641, 1997.

- [2] Morrison, S., Hong, S.L., and Newell, K.M. "Inverse relations in the patterns of muscle and center of pressure dynamics during standing still and movement postures," *Exp Brain Res*, 181, 347-358, 2007.
- [3] Vuillerme, N., and Nougier, V. "Effect of light finger touch on postural sway after lower-limb muscular fatigue," *Arch Phys Med Rehabil*, 84(10), 1560-1563, 2003.
- [4] Fransson, P.A., Kristinsdottir, E.K., Hafström, A., Magnusson, M., and Johansson, R. "Balance control and adaptation during vibratory perturbations in middle-aged and elderly humans," *Eur J Appl Physiol*, 91(5-6), 595-603, 2004.
- [5] Kitabayashi, T., Demura, S., Noda, M., and Yamada, T. "Gender differences in body-sway factors of center of foot pressure in a static upright posture and under the influence of alcohol intake," *J Physiol Anthropol Appl Hum Sci*, 23(4), 111-118, 2004.
- [6] Noda, M., Demura, S., Yamaji, S., and Kitabayashi, T. "Influence of alcohol intake on the parameters evaluating the body center of foot pressure in a static upright posture," *Percept Mot Skills*, 98(3 Pt 1), 873-887, 2004.
- [7] Demura, S., Kitabayashi, T., Noda, M., and Aoki, H. "Age-stage differences in body sway during a static upright posture based on sway factors and relative accumulation of power frequency," *Percept Mot Skills*, 107(1), 89-98, 2008.
- [8] Degache, F., Serain, É., Roy, S., Faiss, R., and Millet, G.P. "The fatigue-induced alteration in postural control is larger in hypobaric than in normobaric hypoxia," *Sci Rep*, 10(1), 483, 2020.
- [9] Hill, M.W., and Price, M.J. "Carrying heavy asymmetrical loads increases postural sway during quiet standing in older adults," *Aging Clin Exp Res*, 30(9), 1143-1146, 2018.
- [10] Bedo, B.L.S., Pereira, D.R., Moraes, R., Kalva-Filho, C.A., Will-de-Lemos, T., and Santiago, P.R.P. "The rapid recovery of vertical force propulsion production and postural sway after a specific fatigue protocol in female handball athletes," *Gait Posture*, 77, 52-58, 2020.
- [11] Demura, S., Kitabayashi, T., and Noda, M. "Selection of useful parameters to evaluate center-of-foot pressure movement," *Percept Mot Skills*, 103(3), 959-973, 2006.
- [12] Masani, K., Vette, A.H., Kouzaki, M., Kanehisa, H., Fukunaga, T., and Popovic, M.R. "Larger center of pressure minus center of gravity in the elderly induces larger body acceleration during quiet standing," *Neurosci Lett*, 422(3), 202-206, 2007.
- [13] Matsuda, T., Takanashi, A., Kawada, K., Miyajima, S., Nogita, Y., Shiota, K., Koyama, T., Uchikoshi, K., Koshida, S., and Hashimoto, T. "The effect of fatigued hip abductors on single-leg stance postural control and muscle control," *Rigakuryoho Kagaku*, 26(5), 679-682, 2011.
- [14] Demura, S., Yamaji, S., Goshi, F., and Nagasawa, Y. "Lateral dominance of legs in maximal muscle power, muscular endurance, and grading ability," *Percept Mot Skills*, 93(1), 11-23, 2001.
- [15] Noguchi, T., Demura, S., and Aoki, H. "Superiority of the dominant and nondominant hands in static strength and controlled force exertion," *Percept Mot Skills*, 109(2), 339-346, 2009.
- [16] Noguchi, T., Demura, S., Nagasawa, Y., and Uchiyama, M. "The practice effect and its difference of the pursuit rotor test with the dominant and non-dominant hands," *J Physiol Anthropol Appl Hum Sci*, 24(6), 589-593, 2005.
- [17] Society for Physical Fitness Standards Research in Tokyo Metropolitan University (Ed.). [New Physical Fitness Standards of Japanese People], Fumaido, Tokyo, Japan, [in Japanese], 2000, pp. 20-85.
- [18] Takahashi, K., Demura, S., and Aoki, H. "Effects of lower limbs exercise with light and heavy loads on the center of gravity sway," *American Journal of Sports Science and Medicine*, 9 (1), 8-12, 2021.
- [19] Aoki, H., Demura, S., Kawabata, H., Sugiura, H., Uchida, Y., Xu, N., and Murase, H. "Evaluating the effects of open/closed eyes and age-related differences on center of foot pressure sway during stepping at a set tempo," *AAR*, 1(3), 72-77, 2012.
- [20] Dolcos, F., Rice, H.J., and Cabeza, R. (2002) "Hemispheric asymmetry and aging: right hemisphere decline or asymmetry reduction," *Neurosci Biobehav Rev*, 26(7), 819-825, 2002.
- [21] Roy, E.A., Bryden, P., and Cavill, S. (2003) "Hand differences in pegboard performance through development," *Brain Cogn*, 53(2), 315-317, 2003.

