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Perceived Postural Instability during Simulated Lifting Tasks in Construction Workers

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Abstract: There are various occupational fatal/nonfatal injuries in construction industry, in which falls or fall-related injuries have been identified as a leading cause. The instability of working postures can lead to falls in construction workers. This research investigated the effects of lifting posture (6 levels), lifting load (2 levels: 0KG, 10KG) and standing surface slope (2 levels: 0°, 18°) on postural instability (PI) based on subjective perceptions (0-10 rating scale). Thirty young subjects participated in this study and performed six simulated lifting postures under four different experimental conditions (2 lifting loads × 2 standing surface slopes). Results showed statistically significant main effects ($p<0.0005$) of each factor on PI. Both sloped standing surface and lifting load could increase PI (except full squatting), however, lifting load had a larger effect on PI than sloped standing surface. There were also significant interactions between lifting posture and lifting load in the conditions of both flat (p=0.000) and sloped (p=0.000) standing surfaces, between standing surface and lifting postures only under no load condition (p=0.000), between standing surface and lifting load only for full squatting posture (p=0.000). Among 6 lifting postures, full squatting was very different that it's more stable with lifting load than no load in flat standing surface condition, and more stable in the sloped standing surface condition than in the flat when no lifting load. The reliability of subjective perceptions on PI, as assessed by Intraclass Correlation Coefficient-ICC (3, 1), was excellent in 10KG load conditions (0°: ICC=0.919; 18°: ICC=0.940), and good (0°, ICC=0.890) to moderate (18°, ICC=0.673) in no load (0KG) conditions. The results demonstrated that participants could consistently rate their perceptions of PI, especially when the PI level was high. The three factors had not only significant main effects on PI, but also significant and complicated second-order interaction effects. These findings implicated that all above three factors should be taken into account at the same time to prevent falls in construction workers.

Keywords: Postural Instability, Construction Safety, Balance, Falls, Lifting Task

1. Introduction

Construction industry has been identified as one of the most hazardous industries (Choi et al., 2019; Jo et al., 2017). There are various occupational fatal/nonfatal injuries in construction industry, in which falls or fall-related injuries have been identified as a leading cause (Choi et al., 2019). Postural instability (PI) is one of most common factors related to injuries from falling in construction industry (Hsiao and Simeonov, 2001; Jebelli et al., 2016). Since completion of the construction work usually requires maintaining a variety of postures (Paquet et al., 2005), and some of them may increase the risk of falling (Gauchard et al., 2001). In the previous studies, center of pressure related measures were most widely used (DiDomenico et al., 2011; Jebelli et al., 2016; Qiu & Xiong, 2015) to measure PI objectively. Some studies pre-assumed human body is less stable with lifting load than without (Jebelli et al., 2015), on a sloped standing surface than the flat one (Simeonov et al., 2009). DiDomenico et al. (2010) explored construction workers' perceptions of postural instability upon standing after working in several different postures. Few researchers studied the effects of lifting postures on PI considering the potential interactions with other factors based on subjective perceptions. This study investigated the effects of lifting posture (LP), lifting load (LL) and standing surface slope (SS) on PI and their interactions based on subjective perceptions.

2. Methodology

A within-subject repeated measures design was utilized with three factors: LP (6 levels), LL (2 levels: 0KG, 10KG) and SS (2 levels: 0° slope, 18° slope). The selected six lifting postures were natural standing (P0), natural standing with the arms raised to 90˚ in the sagittal plane (P1), full squatting (P2), forward bending (P3), bending with left turning (P4) and overhead carrying (P5). All the postures were determined with the references to a field survey and previous studies (DiDomenico et al., 2010; Goldsheyder et al., 2002). The 18° slope was referred to the inclination angle of a low-slope type roof (Simeonov et al., 2009), and 10 KG load was determined considering the real application in the construction site, the feasibility of the experiment and the reference (HSE, 2016). A 10-point rating scale (higher score means higher PI) was used for measuring perceived postural instability (PPI). Thirty healthy young males (28.2 ± 4.7 years old) participated in this study, each of them was asked to lift up a load box for 10 seconds in six postures under four experimental conditions (Flat Surface Session: F+0kg and F+10kg conditions, Sloped Surface Session: S+0kg and S+10kg conditions) and then give ratings. After one session was finished, each participant was asked to perform one randomly selected task in each condition and give ratings again. The Intra-class Correlation Coefficients (ICC) estimates and absolute difference (AD) between test and retest ratings on the randomly selected task were calculated to assess the reliability of the participants' perceived postural instability. Paired-samples t-test and AVOVAs were conducted to study the effects of above three factors and their interactions.

3. Results

The reliability was excellent in F+10kg (ICC=0.919) and S+10kg (ICC=0.940) conditions, good in the F+0kg condition (ICC=0.890) and moderate under S+0kg condition (ICC=0.673) according to the guidelines (Koo and Li, 2016). Also, the average AD was relatively low (<0.65) in all conditions. The average PPI (**Figure 1**) showed that P0 was stable and P3-P5 were relatively instable in all conditions. P1 was very stable in 0 KG and very instable in 10 KG conditions. P2 was relatively stable except in the F+0kg condition. Moreover, except P2, average PPI was higher in 10 KG lifting load conditions than in 0 KG conditions, and was higher in sloped standing surface conditions than that in flat. ANOVA and paired-samples t-test showed LP ($p<0.0005$ in each condition), LL ($p<0.0005$) and SS ($p<0.0005$) significantly affect PPI. There was a statistically significant increase of 3.05 (95% CI, 2.81 to 3.29) in average PPI from 0 KG (1.41 ± 1.40) to 10 KG (4.47 ± 2.25) condition, and a significant increase of 0.47 (95% CI, 0.29 to 0.65) from flat (2.71 ± 2.39) to sloped (3.17 ± 2.43) standing surface condition. There was a significant three-way interaction among three factors ($p=0.000$). Two-way AVOVAs showed statistically significant second-order interactions between SS and LL only for P2 ($p=0.000$), between LP and LL for both flat ($p=0.000$) and sloped ($p=0.000$) standing surfaces, and between SS and LP for without load (0 KG, $p=0.000$), but not for with load (10KG, $p=0.442$).

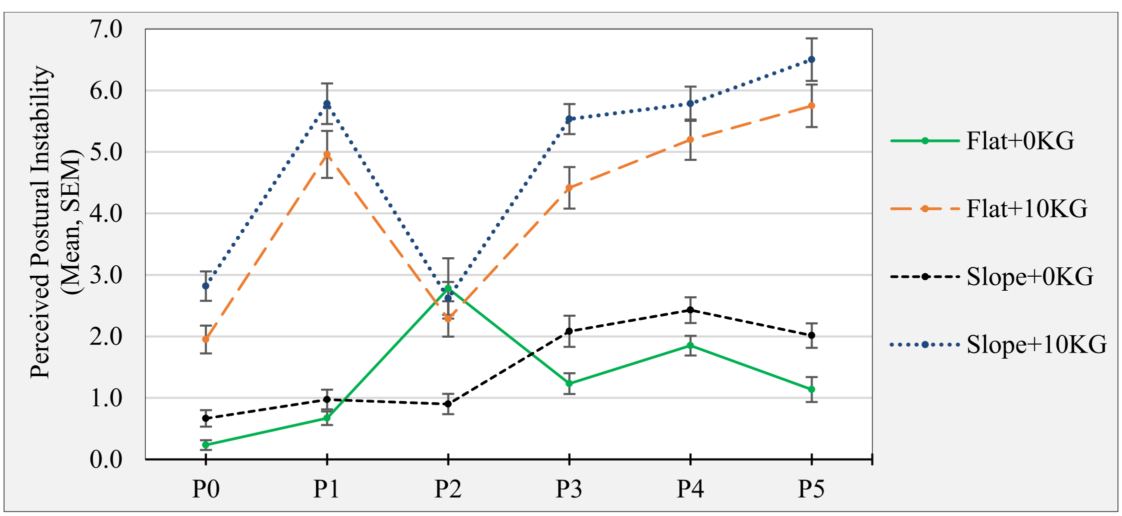

Figure 1. Perceived postural instability of six lifting postures (P0-P5) under four different experimental conditions

4. Discussion and Conclusion

Results showed all three factors could significantly affect perceived postural instability. Both sloped standing surface and lifting load could increase the average PPI (except P2), but the increase caused by lifting load (3.05) was much larger than that caused by sloped standing surface (0.47). Moreover, according to above interaction results, the lifting load could affect the result of interaction between the other two factors, however, the sloped standing surface couldn't. All above indicated the lifting load had a larger effect than sloped standing surface. One possible reason could be the lifting load can significantly change the location of center of mass, thus decrease the body's steadiness. Another possible reason could be related to our experiment design, in which 10 KG load could be considered as relatively high lifting weight for most of participants; 18° inclination angle, on the contrary, was referred to a low-slope type roof.

Among the six lifting postures, full squatting posture (P2) was very different. For P2, there was a non-significant ($p = 0.238$) decrease of 0.50 in PPI from 0 KG to 10 KG in the flat standing surface condition, and a significant ($p = 0.000$) increase of 1.72 in the sloped standing surface condition. There was a significant ($p = 0.001$) decrease of 1.88 from flat to sloped standing surface in 0 KG condition, and a non-significant ($p = 0.346$) increase of 0.33 in 10 KG condition. Those results indicate P2 is more stable with lifting load than without in flat standing surface condition, and more stable in the sloped standing surface condition than in the flat when no lifting load. This is reasonable when considering the unique characteristics of P2, which makes people fall backwards easily when maintaining P2 without carrying a load in hands on a flat standing surface. However, carrying a load in front changes the location of center of mass by shifting it forward and thus the projection of center of gravity is closer to the center of base of support. The incline of the surface could provide an up-forward support force to the heels to offset the gravity in down-backward direction. Therefore, carrying a load or standing on a sloped surface with heels raised could increase the steadiness of the body when maintaining P2.

In addition, the low AD and high ICC values, found in this study, indicated the participants were able to give reliable and consistent subjective ratings on the perceived postural instability, especially when the PI level was high. The higher ICC values were found in the 10KG conditions, in which the average PPI was relatively higher than no load conditions (see Figure 1). This could be explained using the classical psychophysics theory, that only when the physical stimuli is stronger than some critical threshold, can people consciously experience it (Gescheider, 1985; Noble and Robertson, 1996). Higher PI means stronger sensory stimulus, which could easily produce more noticeable difference in the sensation.

In conclusion, this study demonstrated that participants could consistently rate their perceived postural instability, especially when the postural instability level was high. Lifting posture, lifting load and standing surface slope had not only significant main effects on perceived postural instability, but also significant and complicated second-order interaction effects. These findings implicated that all above three factors should be taken into account at the same time to prevent falls in construction workers.

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