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Assessment of perceived traumatic injury hazards during drywall hanging

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Abstract

Workers who handle massive and bulky drywall sheets are at a high risk of traumatic injuries. The objective of this study is to identify the drywall handling tasks and activities which are directly perceived as hazardous by workers. A questionnaire survey was conducted for the study. In the questionnaire, three hanging tasks were included: (1) hanging drywall on the ceiling; (2) hanging drywall on the upper half of the wall; and (3) hanging drywall on the lower half of the wall. Each of the three tasks was divided into 10 to 12 constituent activities. Supportive elevated equipment was also evaluated. Workers were instructed to rate the drywall-hanging tasks/activities and elevated equipment in regard to fall potential, perceived physical stress, and risk of being struck by or against objects, using a seven-point scale (1 = hardly at all to 7 = a great deal). Results from this study indicate that all the ratings of fall potential, perceived physical stress, and risk of being struck by or against objects while hanging drywall on the ceiling were greater than while performing the other two tasks. Activities involving lifting/carrying/holding drywall sheets were rated as most physically stressful. Workers perceived greatest physical stress and fall potential when wearing stilts as compared to using ladders or scaffolds. The findings of this study provide detailed information directly from the workers about the hazards associated with drywall hanging. Results from this study will assist in focusing future research efforts on the most hazardous tasks and activities of drywall hanging.

Relevance to industry

Construction workers who perform drywall installation have high occupational incident rate for traumatic injury. Handling massive and bulky drywall sheets increases the potential for physical stress, falls and struck by and against objects. A questionnaire was designed to collect injury information directly from construction workers who performed drywall hanging and to identify perceived hazards associated with drywall hanging. Prior to this study, there has been little substantive research to evaluate the excessive stresses imposed on this workforce.

Keywords: Drywall installation; Traumatic injuries; Physical stress; Fall injury; Struck by and against objects

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1. Introduction

According to the Bureau of Labor Statistics (BLS, 1998), there were 476 200 injury cases and 217 900 lost workday cases in the construction industry in 1995. The total number of occupational injuries was fifth among all major industry divisions, whereas the injury incidence rate (10.4 per 100 full-time workers) was the highest in the nation. The construction industry also had the highest days-away-from-work case-incidence rate (4.1 per 100 full-time workers). One specialty of construction occupations – drywall installers – was found to have higher traumatic injury incidence rates (7.7 and 5.4 per 100 workers for 1992 and 1993, respectively) than all construction workers combined (5.2 for 1992 and 4.9 for 1993) (Chiou et al., 1997). In Washington state, the composite incidence rate for drywall installation (1992 to 1994) was 23.58 per 100 full-time workers, which was the highest of all industries (Washington State Department of Labor and Industries, 1996). In a focus-group study, drywall installation was considered to be one of the two most difficult carpentry specialties (Warren et al., 1994). This study also reported that lifting and carrying drywall sheets were reported as the most difficult tasks by carpenters who performed drywall installation.

In the construction industry, drywall installation means drywall hanging, which is conducted by drywall installers and carpenters. Drywall finishing is usually carried out by a different group of workers – the painters. Drywall installation is a several-step process. Drywall sheets have to first be cut to dimensions to accommodate any electrical fixtures, openings, windows, or doors. Drywall sheets that are attached to ceiling or walls are fastened to wood or metal studs using electrical screw guns or hammers. Once the drywall sheet has been hung, taping and joint compounds are applied to the joints. The whole process is completed by sanding the joint until the wall is smooth. To hang drywall onto the ceiling or the wall, drywall installers are constantly involved in handling heavy and bulky materials. A typical gypsum drywall sheet weighs from 54 to 224 lb and is 4-feet wide, 8- to 14-feet long, and 3/8- to 1-in thick. Handling drywall sheets from where they are stored to where they are being hung exposes drywall installers or carpenters to potential ergonomic risk factors, such as awkward postures and excessive use of force. The top five leading injury events for drywall installers were overexertion, falls to a lower level, bodily reaction, struck by an object, and falls on the same level, accounting for more than 78% of all traumatic injuries of drywall installers (Chiou et al., 1997). There has been a significant amount of research on the association between drywall installation and illness (Fischbein et al., 1978, 1979; Freed et al., 1991). However, there has been minimal research conducted to examine drywall installation and ergonomic hazards (e.g., overexertion) or traumatic injuries associated with falls and being struck by or against an object.

There are a variety of ergonomic assessment methods and instruments available for assessing hazardous tasks and activities. However, in the construction industry, there are many practical limitations. Unlike many manufacturing jobs, construction tasks are highly dynamic, unstructured, and often require workers to handle large-sized materials, perform jobs in a confined space, and in varying environmental conditions. These unique characteristics of the work environment – constantly changing tasks, materials, work site layout, and environmental condition – make it difficult to apply objective ergonomic assessment tools (e.g., electromyography, lumbar motion monitor or other motion analyzers, and force platform) at construction sites. Therefore, information directly from experienced workers is valuable to help identify problems and high-risk tasks and activities. The objective of this study is to identify the hazardous tasks as a whole, and specific activities of each task of drywall hanging which is directly perceived as a stressful activity by the workers in terms of physical stress, fall potential, and risks of being struck by or against an object. Tasks and activities with high risks for traumatic injuries can then be identified, so that ergonomic principles can be applied to modify the work methods and environment or to select an appropriate device.

2. Method

A questionnaire, which was designed at the National Institute for Occupational Safety and Health

Table 1
List of drywall hanging tasks and activities

Task	Activity
Hang drywall on ceiling	1. Assemble scaffold and tools at site 2. Ascend scaffold/stilts 3. Measure for openings 4. Lift drywall to be cut at ground level 5. Carry drywall to be cut at ground level 6. Position drywall to be cut at ground level 7. Measure and cut drywall 8. Apply glue to ceiling joists 9. Lift drywall to scaffolding 10. Lift/carry/hold drywall to overhead position 11. Secure edges with drywall nails 12. Secure filed with drywall screws
Hang drywall on upper half of the wall	1. Assemble tools at the work site 2. Measure walls for size and openings 3. Lift drywall to be measured and cut 4. Carry drywall to be measured and cut 5. Position drywall to be measured and cut 6. Measure and cut drywall 7. Apply glue to studs 8. Lift/carry/hold drywall to position 9. Secure edges with drywall nails 10. Secure filed with drywall screws
Hang drywall on lower half of the wall	1. Assemble tools at work site 2. Measure walls for size and openings 3. Lift drywall to be measured and cut 4. Carry drywall to be measured and cut 5. Position drywall to be measured and cut 6. Measure and cut drywall 7. Apply glue to studs 8. Lift/carry/hold drywall to position 9. Secure edges with drywall nails 10. Secure filed with drywall studs

(NIOSH) for this study, was used to identify perceived hazardous activities associated with drywall hanging. The first part of this questionnaire consisted of demographic data including gender, weight, height, years of experience hanging drywall, and injury history (frequency of past injuries).

The second part of the questionnaire addressed issues associated with three drywall hanging tasks: (1) hanging drywall on the ceiling; (2) hanging drywall on the upper half of the wall; and (3) hanging drywall on the lower half of the wall. Each of the three tasks was further divided into 10 to 12 constituent activities as shown in Table 1. The volunteer questionnaire respondents were asked to characterize each of the three hanging tasks and the constituent activities in terms of fall potential, perceived physical stress, and risk of being struck by or against objects. A seven-point scale was used where:

1 = hardly at all. The task or activity has very low physical demand, propensity for loss of balance leading to a possible fall incident, or risks of getting struck by or against an object.

7 = a great deal. The task or activity is highly physically demanding, likely to cause loss of balance leading to a fall incident, and can easily involve being struck by or against an object.

The volunteer questionnaire respondents were also asked to identify the body part(s) affected for each of the three hanging tasks and the constituent activities in terms of perceived physical stress and risk of being struck by or against objects. The body-parts affected in the survey included: neck, shoulder, elbows, wrists/hands, upper back, lower back, hips/thighs, knee, and ankles/feet.

The third part of the questionnaire addressed the physical stress, fall potential, and risks of being struck by or against an object associated with the use of three common assistive elevated devices during drywall installation. Ratings for each of the elevated devices, including scaffolds, step ladders, and stilts, were also made on a seven-point scale, as described earlier.

Sixty carpenters with at least 6 months of drywall-hanging experience from the Carpenters' Union located in Charleston, West Virginia, participated in this study. Questionnaires were distributed to groups of volunteer subjects during local

union meetings by trained contractors. Access to volunteer subjects for questionnaire administration was obtained by the contractor (the Construction Program of West Virginia University) in conjunction with the Chemical Valley Carpenters' District Council. Included in the instructional session was practice in filling out a portion of the questionnaire. Experienced contractors remained throughout the questionnaire-administration session to answer questions and assist in its completion of the questionnaire. The questionnaire was pilot tested with nine subjects using the exact procedures planned for the actual survey and final changes were made prior to its administration.

The statistical analyses were performed using the Statistical Analysis System (SAS, 1996). Analyses of variance (ANOVA) were performed to determine the effect of three different hanging tasks on the ratings of physical stress, fall potential and risk of being struck by or against objects. For the significant results, multiple comparisons were performed to further compare the three tasks. Similar procedures were used to determine the effect of different elevated devices on the three ratings.

3. Results

The 60 subjects (mean age: 44 years $\pm$ 9.6 standard deviation [SD]) participating in this study were carpenters with an average drywall installation experience of 14 yr $\pm$ 8.7 SD. Subjects had a mean body weight of 87 kg $\pm$ 10.1 SD and mean body height of 179 cm $\pm$ 5.5 SD. Their mean working hours per week were 29 h $\pm$ 15 SD, and 32 out of the 60 subjects worked 40 or more hours per week. Nine of the subjects had an injury history associated with drywall installation. They suffered overexertion injuries ($n = 3$), falls ($n = 3$), being struck by/against ($n = 1$) an object, or more than one of the above three injuries ($n = 2$). More than 90% of subjects hung large-sized drywall sheets (4 ft $\times$ 10 ft or larger) during their work.

3.1. Evaluation of drywall hanging tasks and activities

Results from ANOVA showed that the tasks were highly significantly different for all three ratings: physical stress, fall potential, and risks of being struck by/against an object (all p values < 0.01). Pair-wise contrast comparisons revealed that all three mean ratings of fall potential, perceived physical stress, and risk of being struck by or against objects, while hanging drywall on the ceiling, were greater than while performing the other two tasks (all p values < 0.04). The perceived fall potential for hanging drywall on the upper half of the wall was significantly higher than that of the lower half of the wall ($p < 0.05$). However, the mean ratings of physical stress and risk of being struck by/against objects for hanging drywall onto the upper half of the wall were not significantly different from those of hanging drywall on the lower half of the wall (both p values > 0.05). Fig. 1 illustrates the mean perceived hazards and standard errors for the three drywall hanging tasks. Subjects consistently perceived the greatest physical stress, fall potential, and risks for being struck by or against an object while hanging drywall onto the ceiling.

Among the 12 constituent activities associated with hanging drywall on the ceiling, lifting/carrying/holding drywall in an overhead position was perceived as producing the most physical stress (mean rating = 5.6), followed by the activity of lifting drywall to scaffolding (mean rating = 5.3) as listed in Table 2. Other leading activities producing physical stress were carrying drywall to be cut at ground level (mean rating = 4.6), lifting drywall to

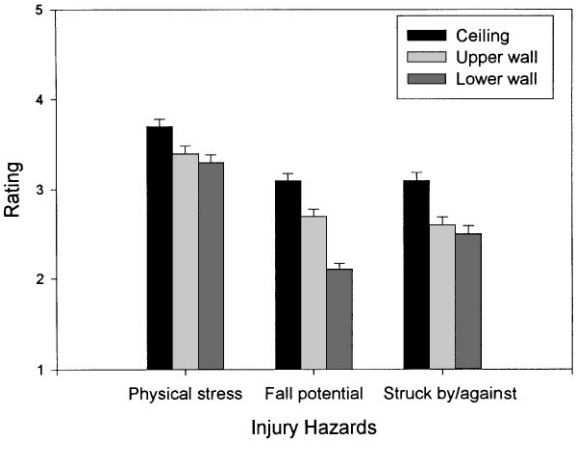

Fig. 1. Mean perceived injury hazards and standard errors for three drywall hanging tasks ($n = 60$).

Table 2
Perceived physical stress for drywall hanging activities ($n = 60$)

Task	Activity	Mean Rating ± Standard Errors
Hang drywall on ceiling	Lift/carry/hold drywall to an overhead position	5.6 ± 0.24
	Lift drywall to scaffolding	5.3 ± 0.23
	Carry drywall to be cut at ground level	4.6 ± 0.24
	Lift drywall to be cut at ground level	4.2 ± 0.24
	Secure edges with drywall nails	3.9 ± 0.24
Hang drywall on the upper half of the wall	Lift/carry/hold drywall to position	4.9 ± 0.26
	Carry drywall to be measured and cut	4.6 ± 0.25
	Lift wall to be measured and cut	4.3 ± 0.26
	Position drywall to be measured and cut	4.0 ± 0.26
	Secure edges with drywall nails	3.2 ± 0.24
Hang drywall on the lower half of the wall	Lift/carry/hold drywall to position	4.7 ± 0.27
	Carry drywall to be measured and cut	4.6 ± 0.27
	Lift drywall to be measured and cut	4.1 ± 0.27
	Position drywall to be measured and cut	3.9 ± 0.27
	Secure edges with drywall nails	3.0 ± 0.26

be cut at ground level (mean rating = 4.2) and securing edges with drywall nails (mean rating = 3.9). The mean ratings of lifting/carrying/holding drywall in an overhead position and lifting drywall to scaffolding were significantly higher than those of all other ceiling-installation activities (all p values < 0.02).

As clearly seen in Table 2, both tasks of hanging drywall on the upper and lower halves of the wall had identical leading activities which caused physical stress. Subjects consistently rated the activity of lifting/carrying/holding drywall into position as most physically stressful. Furthermore, the mean ratings of the top two activities (Table 2) – lifting/carrying/holding drywall into position and carrying drywall to be measured and cut – were significantly greater than those of all eight other activities (all p values < 0.04), but they were not statistically different from each other ($p > 0.05$). This finding was valid for hanging drywall onto both upper and lower halves of the wall (Table 2).

Among all the activities (Table 3) performed during ceiling drywall installation, the mean perceived fall potential for ascending scaffold/stilts (mean rating = 4.6) was the greatest, which was also significantly greater than that for all other activities ($p < 0.05$). Subjects perceived the second greatest fall potential as lifting/carrying/holding drywall to an overhead position (mean rating = 4.1) to install drywall onto the ceiling (Table 3). For hanging drywall on the upper half and lower half of the wall, lifting/carrying/holding drywall to position (mean rating = 3.2) and carrying drywall to be measured and cut (mean rating = 2.4), had the next highest ratings for fall potential (Table 3).

Table 4 shows the three leading activities – lifting drywall to scaffolding (mean rating = 4.0), lifting/carrying/holding drywall to an overhead position (mean rating = 3.7), and assembling scaffold and tools at site (mean rating = 3.5) – performed during hanging drywall onto the ceiling were perceived as having high risks for being struck by or against an object. For both tasks of hanging drywall onto the lower half and upper half of the wall (Table 4), lifting/carrying/holding drywall to position was rated as having the greatest risk of being struck by or against an object (mean ratings were 3.0 and 2.9 for lower half and upper half, respectively).

Figs. 2 and 3 present the most affected body parts subject to physical stress and risks of being struck by/against objects. For ceiling tasks, subjects

Table 3
Perceived fall potential for drywall hanging activities ($n = 60$)

Task	Activity	Mean Rating ± Standard Errors
Hang drywall on ceiling	Ascend scaffold/stilts	4.6 ± 0.24
	Lift/Carry/Hold drywall to overhead position	4.1 ± 0.26
	Assemble scaffold and tools at site	3.9 ± 0.27
	Lift drywall to scaffolding	3.8 ± 0.27
	Apply glue to ceiling joints	3.3 ± 0.25
Hang drywall on the upper half of the wall	Lift/Carry/Hold drywall to position	3.2 ± 0.26
	Carry drywall to be measured and cut	2.9 ± 0.24
	Secure edges with drywall nails	2.9 ± 0.27
	Secure field with drywall screws	2.9 ± 0.28
	Lift drywall to be measured and cut	2.7 ± 0.26
Hang drywall on the lower half of the wall	Carry drywall to be measured and cut	2.4 ± 0.24
	Position drywall to be measured and cut	2.3 ± 0.22
	Lift/Carry/Hold drywall to position	2.3 ± 0.24
	Lift drywall to be measured and cut	2.2 ± 0.22
	Measure and cut drywall	2.1 ± 0.23

Table 4
Perceived risk of being struck by or against an object for drywall hanging activities ($n = 60$)

Task	Activity	Mean Rating ± Standard Errors
Hang drywall on ceiling	Lift drywall to scaffolding	4.0 ± 0.38
	Lift/Carry/Hold drywall to overhead position	3.7 ± 0.32
	Assemble scaffold and tools at site	3.5 ± 0.27
	Ascend scaffold/stilts	3.4 ± 0.26
	Carry drywall to be cut at ground level	3.2 ± 0.34
Hang drywall on the upper half of the wall	Lift/Carry/Hold drywall to position	2.9 ± 0.26
	Lift drywall to be measured and cut	2.8 ± 0.35
	Carry drywall to be measured and cut	2.7 ± 0.31
	Position drywall to be measured and cut	2.7 ± 0.31
	Measure and cut drywall	2.6 ± 0.31
Hang drywall on the lower half of the wall	Lift/Carry/Hold drywall to position	3.0 ± 0.34
	Lift drywall to be measured and cut	2.7 ± 0.27
	Carry drywall to be measured and cut	2.7 ± 0.28
	Position drywall to be measured and cut	2.7 ± 0.26
	Measure and cut drywall	2.6 ± 0.28

identified physical stress primarily in their neck, shoulders, and lower back at 27.5%, 23.5%, and 21.6%, respectively. For hanging drywall on the upper half of the wall, 28.8% of the subjects reported upper back physical stress, and 26.9% reported neck physical stress. Physical stress was most often reported for the lower back (33.3%), shoulders (16.7%), and wrists and hands (16.7%) when hanging drywall on the lower half of the wall. The head was the target body part (40%) subject to

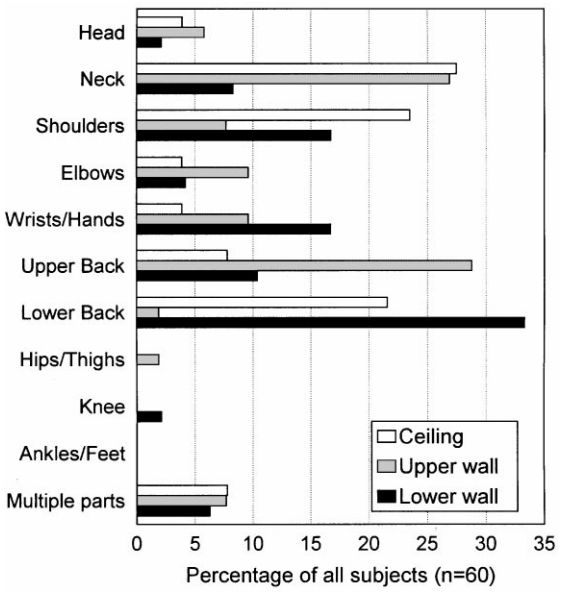

Fig. 2. Affected body parts subject to physical stress in different tasks ($n = 60$).

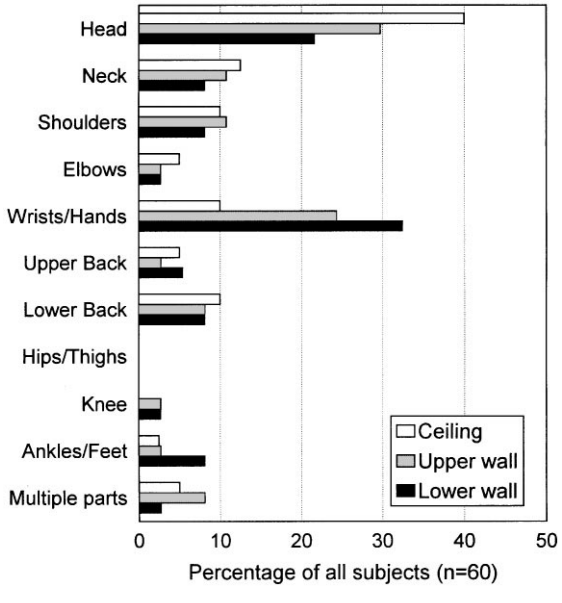

Fig. 3. Affected body parts for risks of being struck by or against an object in different tasks ($n = 60$).

the risk of being struck by or against an object when performing ceiling drywall installation. For hanging drywall on the upper half of the wall, 29.7% of the subjects reported head, and 24.3% reported wrists and hands as being at risk of being struck by or against an object. These two body parts were also most frequently affected when workers were struck by or against an object during drywall installation to the lower half of the wall (Fig. 3). Regardless of the tasks, the back was the body part most subject to physical stress. The head appeared to be the most affected body part while being struck by/against objects.

3.2. *Evaluation of three supportive elevated equipment* (*stilts, step ladders, and scaffolds*)

Results from ANOVA indicated that the effect of elevated equipment was highly significant on physical stress ($p < 0.001$) and fall potential ($p < 0.001$). Fig. 4 shows the mean ratings and standard errors for the three elevated equipment devices – stilts, step ladders, and scaffolds – commonly used for performing ceiling tasks. The physical stress caused by the use of stilts was significantly greater than that of either scaffold or step ladders (both p values < 0.001). However, the physical stress produced by the use of scaffolds did not differ from that of step ladders ($p > 0.05$). For fall potential, a posteriori comparisons showed that the fall potential ratings for the three different types of elevated equipment differed significantly (all p values $<$ 0.03). The mean fall potential rating of stilts (6.0)

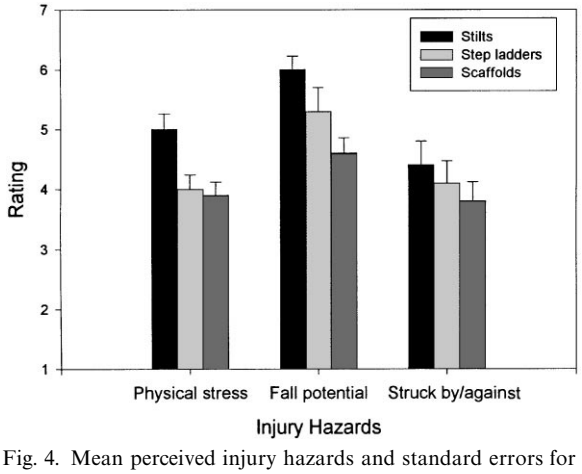

Fig. 4. Mean perceived injury hazards and standard errors for three supportive elevated equipment ($n = 60$).

was significantly greater than that of step ladders (5.3) and scaffolds (4.6) (both p values < 0.01). The fall potential of step ladders (5.3) was significantly greater than that of scaffolds (4.6) ($p < 0.01$).

4. Discussion

Results from Fig. 1 indicate that ceiling-hanging tasks were perceived as most stressful in terms of physical stress, fall potential, and being struck by or against an object, among the three tasks. To perform ceiling installation, workers first have to lift a drywall sheet to an elevated surface (e.g., scaffold, ladder) and then constantly extend their heads/necks, upper extremities, and upper trunks to hold the sheet in place until it is fastened. These activities are very physically demanding and are likely to cause workers' center of mass to reach closer to the outer edges of the base of support and, thereby, increase the probability of falling. In addition, workers may not be able to change their base of support efficiently and accurately in response to any possible momentary loss of balance, because the workers are handling bulky and heavy materials on confined and elevated spaces (e.g., ladders). Workers have to perform tasks such as fastening drywall sheets to studs with a screw gun using one arm, while supporting the weight of the drywall using the other arm extended above the shoulder, and are likely to get struck by or against the drywall sheet if it is not being supported well. This explanation was supported by the finding that the three leading activities, across three tasks with the highest ratings of being struck by or against an object, were performed during ceiling installation.

Examining the leading activities which pose most physical stress found that, across three tasks, activities involving lifting/carrying/holding drywall sheets were the most hazardous (Table 2). This finding is consistent with our previous study of BLS injury data which indicated that more than 85% of overexertion injuries of drywall installers resulted from lifting, holding, or carrying an object (Chiou et al., 1997). Lifting/carrying/holding drywall sheets was even more stressful when performed in an overhead position, meaning ceiling installation, as compared to the same operation performed mostly below shoulder level, for installation on the upper or lower half of the wall.

Neck, shoulders, upper back, and lower back were the body parts subject to the most physical stress, as reported by the subjects (Fig. 2). Additionally, the task of hanging drywall on the lower half of the wall is likely to cause physical stress on wrists and hands (Fig. 2). Very few subjects (less than 5%) perceived physical stress in lower extremities (e.g., knee, ankles, feet, thighs) as compared to the upper extremities. This finding is also consistent with the previous study of injury data of drywall installers (Chiou et al., 1997) which concluded that the back was the most vulnerable area, and accounted for about 27% of total traumatic injuries.

Drywall installation on the upper half of the wall was rated as producing significantly greater fall potential than on the lower half of the wall ($p < 0.05$), but did not produce greater physical stress, or greater potential for being struck by or against an object. The increase in fall potential might be due to the use of the supportive elevated devices needed for installing drywall close to ceiling level. Fig. 4 indicates that stilts are the most hazardous equipment in terms of physical stress and fall potential. Stilts are about 60 cm (2 ft) high and are strapped to the legs, which elevate the human body as well as the location of center of mass. When workers wear stilts to perform tasks, their mobility is increased, in comparison to the use of ladders or scaffolds. However, a worker's base of support is decreased when wearing stilts and the friction between the floor and stilts may be less than that of safety shoes. Stilts reduce workers' flexibility in using lower extremities, which makes it difficult for them to coordinate the movement of other body parts (e.g., trunk). Therefore, when workers are about to lose their balance, they might not be able to use their body movement strategy efficiently to balance their bodies. Under these circumstances, workers consistently perceive the greatest physical stress and fall potential when wearing stilts to perform elevated tasks. The result of this study shows that wearing stilts has the highest fall potential hazard (= 6) compared to any other ratings among tasks and activities. The results of this study also show that ascending scaffold/stilts is

rated as the greatest hazardous fall potential activity among all other activities during ceiling drywall installation. The hazard caused by this elevated equipment (i.e., stilts) is more prominent than the occupational activity associated with its use.

The information acquired through the use of the NIOSH drywall installation questionnaire provides us with an understanding of the potentially hazardous tasks and activities of drywall hanging, based on workers' direct responses. This information should facilitate a more detailed investigation of specific drywall hanging tasks and activities with high risks for traumatic injuries. Future studies should further examine the ergonomic and biomechanical stresses associated with lifting/carrying/holding drywall sheets and evaluate the effectiveness and risks associated with the use of stilts.

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