

Productivity and Physical Load Evaluation of Selected Assistive Tools for Ceiling Drywall Installation

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Abstract: Drywall-hanging laborers, especially during ceiling installation, are at high risk for musculoskeletal injuries, particularly those affecting the lower back and shoulders, due to exposure to frequent manual handling of heavy and bulky loads above shoulder height. Despite the potential for reducing the risk of injury and task-completion time, there are no available studies that investigate the impact of ceiling drywall-hanging assistive tools on total task-completion time and parameters of physical and physiological strain. To solve this problem, we propose to study and compare ceiling drywall installation methods with and without the use of the assistive tools. The long-term goal of this project is to implement a drywall ceiling installation method that incorporates the use of assistive tools, significantly reduces task-completion time, and reduces physical load at the shoulders, neck, and lower back. Our objective is to compare ceiling drywall installation methods with and without the use of the assistive tools, supported by a preliminary study on the efficacy and effectiveness of assistive tools during ceiling drywall installation which did not include the physical load measures. Reducing physical load at the shoulders, neck, and lower back will eventually reduce musculoskeletal injury risk and illness related to ceiling drywall installation, while simultaneously maintaining the productivity rate. Results from this project will determine the need for a large-scale intervention for efficacy testing of the selected method.

Keywords: Musculoskeletal Disorders, Drywall Hanging Laborers, Assistive Tools, Reduced Physical Load

1. Introduction

Frequent handling and carrying of heavy and bulky drywall panels are cited as primary factors in the high prevalence of back and shoulder muscle injuries of drywall carpenters (Lemasters, 1998; Lipscomb, 2000; Lipscomb, 2008; Lipscomb, 1997; Chiou 2000). These studies reported that handling of heavy drywall pieces was reported to be associated with more than 40 percent of the overexertion injuries of drywall hanging workers. Furthermore, they assessed four of the

most common techniques (three horizontal and one vertical) used to lift a drywall panel; each showed that the lifting exerted a minimum of 655 lbs. disc compression force on the low back (L5/S1 region) of the workers whether for a 60 lbs., 80 lbs. or 100 lbs. drywall panel. The same studies found that low back loading while lifting a 100 lbs. drywall panel exceeds 760 lbs., the maximum value recommended by the National Institute for Occupational Safety and Health (NIOSH) in the "Work Practices Guide for Manual Lifting." All four lifting techniques also involved risk of perturbation in postural balance.

Drywall workers had higher rates, specifically for back injuries and shoulder sprain, compared to other carpentry trades such as heavy lifting, pile driving and some other carpentry trades such as millwrighting, cabinet work, etc. (Lipscomb, 1997). The average disc compression force during installation of drywall panels exceeded the value of 760 lbs. (3400 N) disc compression force, set by NIOSH as the recommended action limit (Yuan, 2007). The highest value of disc compression force was found to be 1721 lbs. (7748.8 N) and sustained for an average of 41 minutes or around 8.5% of the total 8-hour work shift. Also, the need to bend the trunk and upper extremity continuously while installing the heavy drywall pieces poses high postural demands on the installers. As a consequence, they tend to lose the body's center of mass, shifting towards the outer edge of a ladder, and thus risk a fall (Pan, 2002).

Earlier interventions dealing with this problem targeted user-friendly nailing aid systems (Mirka, 2003) or overhead drilling bases (Rempel, 2007) or panel carrying tools (Hess, 2010). None of these interventions addressed the physical and physiological concerns of heavy overhead handling, lifting and supporting of drywall panels than an intervention with "deadman" or "hanger's helper." The "deadman" —a narrow piece of scrap drywall used to support the ceiling drywall panel during its installation— was used in a pilot study at a commercial-residential site (with 9-9.5' ceilings). The study's results showed a reduction of the physical, ergonomic exposures of the workers. Based on this concept, a prototype tool ("hanger's help) with adjustable length (8'-13') for supporting drywall ceiling installation was developed and introduced at a similar commercial-residential site (Dasgupta, 2015). Quantitative exposure data (PATH, Buchholz, 1996; 3DSSPP, UMichigan) were collected before and after the intervention. A comparison of these data points established the efficacy of the tool for reducing the physical, ergonomic exposures while supporting drywall during ceiling installation (Dasgupta, 2015; Dasgupta, 2016).

At a construction site, workers or contractors have limited influence to change or make alterations of construction processes (Entzel, 2007). Production is the prime motivator and sometimes can supersede other motivators, even when they are as important as the safety at the workplace (Kines, 2010). Also, if the application of an engineering tool to increase safety necessitates that the worker spends extra time in the work task, it might not be acceptable by the workers themselves. If the time cost of the new procedure becomes high, then it becomes difficult to justify whether the high price paid for a safety tool would be cost-effective (Mirka, 2003). As identified by Dasgupta et al. (2012), the available crew size can be as large as fifteen workers in a commercial construction site, and as low as five in a residential construction site. Only four or five drywall installers are usually available per commercial-residential construction site. Given the shrinkage in the number of drywall installers, reducing ergonomic risk factors (such as awkward postures, overhead arm postures, repetitive movement and force handling), using an assistance tool (e.g., hanger's helper) will likely produce a reduction in WRMSD risk factors for a ceiling installation task, while simultaneously result in a reduction in task completion time. These results show the significance of this proposal: it proposes an installation process that does not jeopardize the productivity of the installer, and at the same time reduces the WRMSD risk factors of the workers.

However, the efficacy and effectiveness study carried out by Dasgupta (2016) did not include the exposure to "neck area," which was a limitation of the study results. Since the "Hanger's Helper" has shown to be of great help for ceiling installation, and shown promising results on its efficacy (again, without reducing workers' productivity), we would like to explore the benefits in productivity, and reduced physical and physiological strain (ROM, HR, RPE, Muscle Activities in the neck, shoulder, and back) by including the use of assistive devices during ceiling drywall installation in the controlled environment.

2. Methods

This project will explore the benefits of productivity, and reduced physical and physiological strain by including the use of assistive devices during ceiling drywall installation. The study will use a sample of construction workers living within the U.S.-Mexico Border region with a predominantly Hispanic population of Mexican origin. An initial screening for inclusion criteria and questionnaire on job contextual factors of skill level, job history, and seniority will also inform all data collection and results. Measures of productivity (time-to-task-completion) and physical and physiological strain such as blood pressure (BP), heart rate (HR), range-of-motion (ROM), rate of perceived exertion (RPE), and surface electromyography (SEMG) muscle activity at the neck, shoulder, and lower back. Additional anthropometric data will also be collected. We will use pre-experimental, single-subject, factorial design, where each participant will randomly complete simulated tasks consisting of hanging ceiling drywall installation under three experimental conditions: 1) two-man (main and

helper) standard /conventional ceiling drywall installation (no assistive tool); 2) two-man (main and helper) “pole” ceiling drywall installation; and 3) one-man manual lifting-device, ceiling drywall installation. All tasks will be performed under controlled environmental conditions. A mockup of a typical wood framing construction (9 1/2 feet standard residential construction height) will be set up for participants to hang three drywall sheets on each session and under the different experimental conditions.

The study will consist of three phases. Phase 1, will determine which of three ceiling installation methods yields the least physical and physiological strain on drywall carpenters. During this initial phase, participants will complete the survey questionnaire, and anthropometric and baseline physiological data will be collected from each participant. Afterward, a remote HR monitor sensor will be placed at the chest. SEMG electrodes will be placed at the identified muscles after preparing the skin. A ten-minute time period will be allowed for electrode conditioning. SMEG resting (baseline) will be recorded. Participants then will be suited with reflective sensors for motion capturing. Depending on the condition, a single or pair of participants will proceed to complete the simulated task of hanging ceiling drywall. When pairing up, measures will be obtained from the main installer and helper separately. Each experimental task condition will be performed during one session per week, over a 3-week time period. Each session will take place after the weekend assuming an at least one-day rest.

The Borg 20-point scale will be used to assess the participant's RPE at three times after completing each drywall sheet installation. Concurrently, we will conduct Phase 2, where time and motion studies will be carried out to determine cycle time, range of motion, and estimation of the shoulder and lower back moments during the task will be performed using analysis of the video. Cycle time and total task-completion time in each of the three experimental conditions and for each participant, as well as ROM angle measurements, will be drawn directly from the analyses of the recordings using the myoVideo® software.

The task will be analyzed using the Optitrack® infrared motion analysis system and Motive® software. This will enable to record body motions that will later serve for a more precise task and biomechanical analysis. Phase 3 will consist of an initial feasibility study focused on limited efficacy after the completion of the different ceiling drywall panel installation methods, followed by an effectiveness study on the selected method at different construction using an uncontrolled, pre-and-post intervention (prospective; longitudinal) approach at different workplace sites, and in different geographical locations.

An initial database file to enter the collected data. Descriptive statistics will be conducted for all collected variables to characterize the sampled participants. The paired t-test and Kruskal-Wallis test will be used for comparisons of continuous variables. The Chi-square and Fisher's exact tests will be used to compare categorical variables. Data collected from the three experimental conditions will be analyzed for significant differences using within subjects-model ANOVA. Statistically significant differences in HR, RPE, and SEMG activity parameters will be indicative of the strain imposed on each participant during each experimental condition.

Additionally, statistically significant differences in posture percentage time, range of motion, and estimated joint moments will also be indicative parameters of the strain imposed on each participant during each experimental condition. Differences in cycle times and time-to-task completion will be indicative of the potential effect on productivity. In Phase 3, the paired t-test and Kruskal-Wallis test will be used for comparisons of continuous variables. The Chi-square and Fisher's exact tests will be used to compare categorical variables. The rejection level for all analyses will be set at $p=0.05$.

3. Expected Results

We expect that results from this proposed experimental study will provide a clearer picture of the biomechanical and physiological workload of the installers' that will help to implement the ergonomic intervention as part of the ceiling installation process in the drywall community. Results will provide evidence for providing advice on selecting specific assistive devices and potential design of new devices or improvement of already existing devices. Also, this will popularize the tool's adoption and will help to introduce it in the construction market as a viable option to reduce daily exposures to unnecessary overexertion during ceiling installation.

3. Concluding Remarks

Self-evaluation and observational study methods, which are often used to assess physical and physiological strain for work-related musculoskeletal injuries and disorders (WRMSD) among construction workers, are prone to exposure misclassification. Work output is of prime importance in the construction industry, and it sometimes supersedes other considerations, — even those as important as ergonomics and safety in the workplace. If the proposed ergonomic intervention demands that the worker spends extra time and resources in the process, most likely it will not be acceptable

either by the workers or the business owners. This proposed research seeks also the feasibility of an effective intervention to reduce daily exposures to unnecessary overexertion during ceiling drywall installation. Therefore, it has the potential to also contribute to a decrease in risk and the burden of musculoskeletal fatigue, pain, & discomfort, injury, and related potential disability of the exposed drywall carpenter installers, while at the same time considering production capability. Our proposed research is relevant to current NIOSH's mission statement, and the National Occupational Research Agenda for Construction targeting research that addresses reducing the risk and burden of musculoskeletal disorders (MSDs) in construction, and eliminate disproportionate risks in construction, in our case, Hispanic, or of Hispanic-origin drywall carpenter installers.

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