ERGONOMICS INVESTIGATION OF WORKERS IN CONSTRUCTION GLASS AND GLAZING TRADE USING THE RAPID ENTIRE BODY ASSESSMENT (REBA) METHOD

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ABSTRACT

The Construction Glass and Glazing (CGG) trade was investigated to identify the most physically stressful work tasks and systematically score and rank the tasks by the required action level using the Rapid Entire Body Assessment (REBA) method. Data were collected by taking pictures and notes at five construction sites. In total, 30 construction glass and glazing workers were observed over 54 days across five CGG construction companies. Manual Materials Handling (MMH) resulted in the highest REBA score for frame installation, glass/panel installation, and loading/unloading tasks (8.8, 8.5, and 7.5 respectively). Screwing/unscrewing/drilling, and caulking activities were among activities with a medium REBA action level of 2 (necessary). Medium to high REBA scores for CGG tasks emphasize a need for future ergonomics interventions to eliminate or reduce the risk of Work-Related Musculoskeletal Disorders (WRMSDs) in this trade.

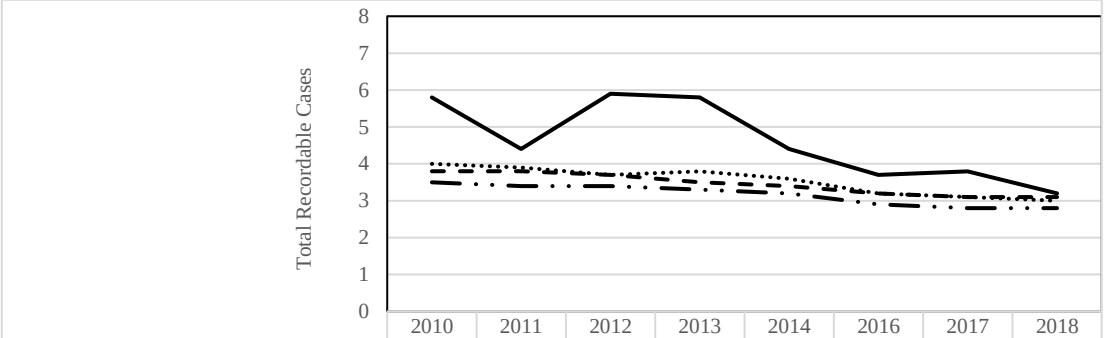
KEYWORDS: *Construction, REBA Method, Musculoskeletal Disorders, Ergonomics & Body Postures*

I. INTRODUCTION

Construction is a high hazard industry with a wide range of activities that may expose construction workers to serious hazards, such as falling from heights, unguarded machinery, being struck by heavy construction equipment, electrocutions, and ergonomics hazards. The construction workers are frequently exposed to Work-Related Musculoskeletal Disorders (WRMSDs) risk factors such as lifting heavy items, bending, reaching overhead, pushing and pulling heavy loads, working in awkward body postures and performing same tasks repetitively [6, 12, 20]. WRMSDs affect muscles, nerves, blood vessels, ligaments, and tendons. WRMSDs are among the most frequently reported causes of lost or restricted work time [35]. According to the U.S. Bureau of Labor Statistics (BLS), in 2015, construction workers experienced a higher incidence rate of WRMSDs (34.6 per 10,000 Full-Time Employees (FTEs)) than all industries combined (32.2 per 10,000 FTEs) [32]. Other studies also have discussed the high incident rate of WRMSDs among construction workers, especially lower back disorders [1, 3, 5, 21, 37, 38].

In 2015, the back was the primary body part affected by WRMSDs and accounted for 17% of nonfatal injuries resulting in days away from work in the construction industry [10]. Although the rate of back injuries in the construction industry decreased by 58% between 2003 and 2015, construction workers still had a higher rate of back injuries in 2015 than in all industries combined (22.3 versus 16.2 per 10,000 FTEs). The risk of back injuries varies among construction subsectors [10]. Construction Glass and Glazing (CGG) contractors reported the highest rate of back injuries (97.8 per 10,000 FTEs) in 2010, followed by masonry contractors (45.3 per 10,000 FTEs) [9]. Glaziers continued to have a higher

rate of injuries and illnesses compared to the national average for all occupations. This may be the result of their exposure to lifting and carrying materials, bending and twisting of the body, and making repetitive motions in performing work tasks [10]. Figure 1 was created based on the BLS data sheets and is a summary of glass and glazing contractors' recordable cases per 100 FTEs. Data for the year 2015 was not available in the BLS data sheets [33, 34].



	2010	2011	2012	2013	2014	2016	2017	2018
Glass and Glazing Contractors	5.8	4.4	5.9	5.8	4.4	3.7	3.8	3.2
Construction	4	3.9	3.7	3.8	3.6	3.2	3.1	3
Private Industry	3.5	3.4	3.4	3.3	3.2	2.9	2.8	2.8
National Average	3.8	3.8	3.7	3.5	3.4	3.2	3.1	3.1

Figure 1. Total Recordable Cases of Nonfatal Occupational Injuries and Illnesses per 100 Full-Time Workers for CGG Workers, Construction, Private Industry, and National Average [34].

Some researchers studied back injuries among construction workers including nailing [2], ironworking [5, 14], concrete work [17], bricklaying [37], masonry [13], construction roofing [39], and carpenters' tasks [18]. Based on the literature reviewed, CGG trade's ergonomics risks have not been adequately investigated. An exploratory sequential mixed-methods study was conducted at the University of Nebraska Lincoln to systematically evaluate glass and glazing trade to identify problems leading to the higher incidence rate of work-related lower back injury and gathering information about improvements that the workers need in this construction subsector.

II. METHODOLOGY

2.1. METHOD

The research was conducted in two phases; the first phase was aimed at developing a CGG job description that was needed to conduct ergonomics analysis on CGG trade [22]. The second phase was ergonomics analysis that was performed by evaluating the CGG trade using two different observational methods called Posture, Activity, Tools, and Handling (PATH) [4], and Rapid Entire Body Assessment (REBA) [19]. This paper is presenting the results of using the REBA method. The main objective was to identify the most physically stressful CGG work tasks, and systematically score and rank the tasks by risk level and required action using the REBA ergonomics assessment method.

REBA method was developed to primarily analyse unpredictable working postures detected in healthcare and service industries. The REBA method was applied to scale the workers' level of risk of developing musculoskeletal injuries, which results in a final score ranging from 1 to 15 (non-existent risk to very high risk) and indicates the magnitude and priority of the measures to be taken [19].

To analyse the tasks and calculate the REBA score, the body parts are divided into two groups: group A and group B. Group A includes the trunk, neck, and legs; each body part is scored according to its position. Then by using Table A, a combined score of group A is calculated and the "Load/Force" score (Appendix A) is added to calculate score A (Figure 2). Group B includes upper arms, lower arms, and wrists. A score of group B is calculated according to body parts scores, and Table B, and then the "Coupling" score (Appendix B) is added and score B is obtained (Figure 2). Group A and B scores are combined, and finally, an activity score (Appendix C) is added to provide the final REBA score (Figure 2).

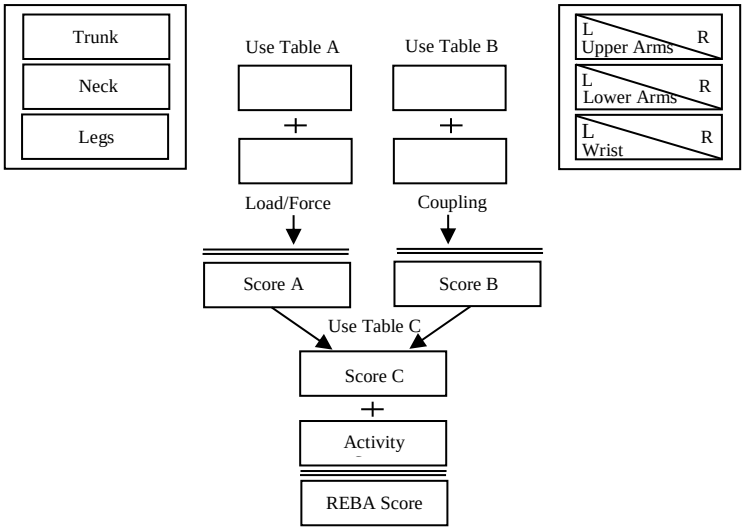


Figure 2. REBA Scoring Adopted from Hignett and McAtamney [19]

According to the final REBA scores for tasks, appropriate action levels are required (Table 1).

Table 1. REBA action levels adopted from Hignett and McAtamney [19]

Action level	REBA score	Risk level	Action (including further assessment)
0	1	Negligible	None necessary
1	2-3	Low	May be necessary
2	4-7	Medium	Necessary
3	8-10	High	Necessary soon
4	11-15	Very high	Necessary NOW

The health care and service industry [8, 11] was not the only occupation that has used the REBA postural assessment; other occupations also have taken advantage of the REBA method for postural assessment of jobs including construction workers [23, 28], agriculture workers [29, 30], manufacturing workers [25, 27, 31, 41], oyster culture workers [16], firefighters [15], potters and sculptors [26], packaging workers [24], and sales assistants [7].

2.2. DATA COLLECTION

2.2.1. Data collection preparation

An online search was conducted to find glass and glazing companies in Nebraska who could be recruited to participate in the research project. Participation in this study was voluntary and the research team targeted small to medium-sized companies in Nebraska in the United States. Five (5) CGG companies agreed to participate, where all companies identified their construction projects as large commercial-industry projects. The companies were City Glass Company (Omaha; 70-75 employees), Bil- Den Glass (Omaha; ± 56 employees), Keystone Glass Company (Omaha, 51 employees), Glass Edge, Inc. (Lincoln; ±45 employees), and Lincoln Glass Inc. (29 employees). The CGG companies that supported our project were not unionized. All companies indicated their construction projects as large commercial-industrial projects.

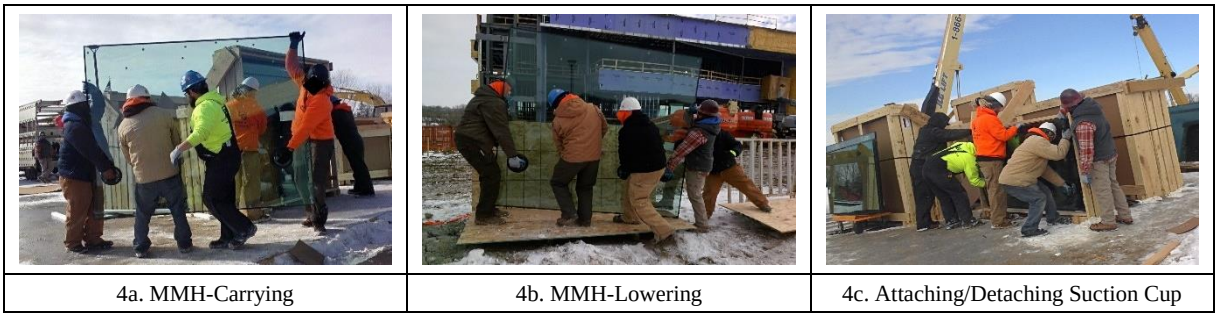
The CGG ergonomics analysis phase was approved by the University of Nebraska Institutional Review Board (IRB) for Human Subjects Research (Accepted in September 2017, IRB # 20170916968EX). An introduction session was held for each company to discuss the aim and objectives of the study. Five different construction sites were observed, and data were collected by taking notes and pictures on site. In total, thirty (30) CGG field workers were followed and observed across the five companies, over 54 days. Participation was voluntary and all participants signed the informed consent form and received a 25 USD gift card for their participation.

2.2.3. Data collection process

Participating CGG companies allowed worksite observations for as long as the research team needed to do their on-site observations and data collection. Three operations observed included curtainwall, storefront, and panelling at each of the five companies. For each CGG operation, five tasks were performed including frame installation, glass/panel installation, finishing jobs, loading and unloading materials, and general tasks. Each CGG task had several activities that were determined through site observations. Glass and glazing workers were observed for approximately 3 months (one observer), for a total of 54 observation days (January, 13 days; February,19 days; and March, 22 days), of which 41 days were productive and used in total, spread over the five companies. 19,300 observations for all three operations were recorded. Data was collected by taking notes and pictures at regular intervals of 60 seconds using a Google Glass Explorer Edition (Foxconn, US). Simple Interval Timer (SIT) application was installed on the observer's iPhone (Foxconn & Pegatron, US), which was synchronized with an Apple Watch (Quanta Computer & Compal Electronics, US) so that the watch was notifying the research analyst to take a photograph at the end of every 60-second interval. These 19,300 observations were used in the CGG evaluations using both PATH (another research paper) and REBA methods. Figures 3, 4, 5, and 6 illustrate some pictures of CGG tasks that were taken during site observations. The data that support the findings of this study are available from the corresponding author, upon reasonable request.

3a. MMH - Placing (Curtainwall)	3b. MMH - Lifting (Storefront)	3c. MMH - Carrying (Storefront)
3d. Drilling (Curtainwall)	3e. Caulking (Storefront)	3f. Shimming (Storefront)

Figure 3. Frame installation



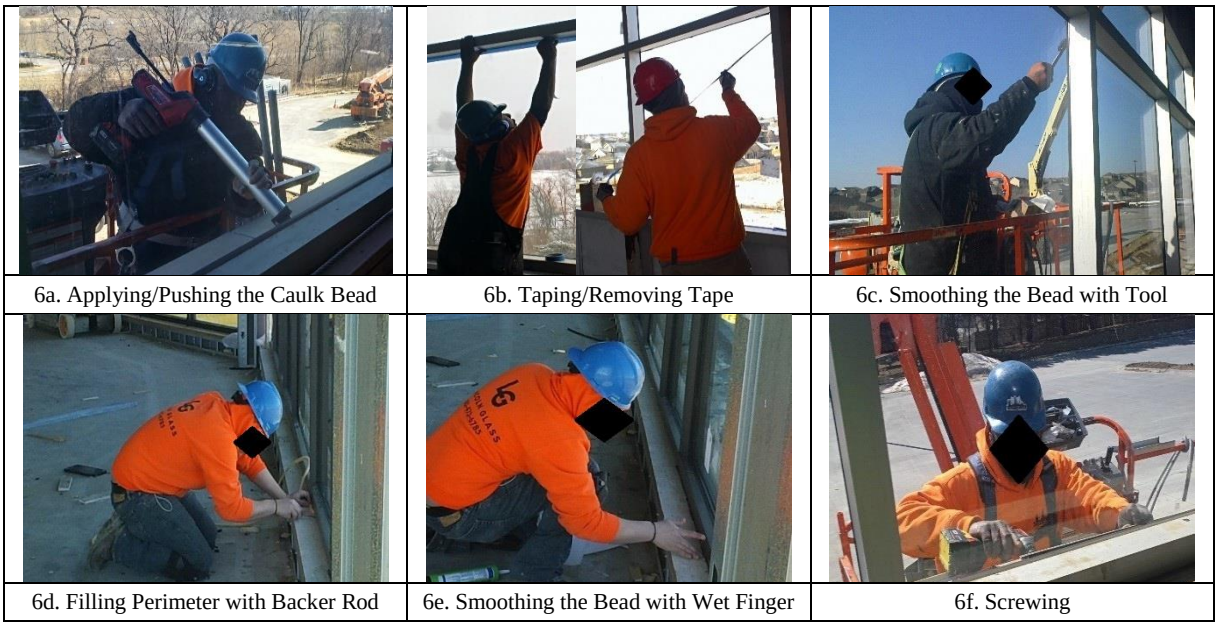
4a. MMH-Carrying	4b. MMH-Lowering	4c. Attaching/Detaching Suction Cup

Figure 4. Manual materials handling-unloading

5a. MMH - Carrying (Curtainwall) | 5b. Screwing (Panelling) | 5c. Attaching Suction Cup (Curtainwall)

5d. Pulling Panel Cover (Panelling) | 5e. Shimming (Panelling) | 5f. Putting Vinyl-Gasket (Storefront)

Figure 5. Glass/Panel installation



6a. Applying/Pushing the Caulk Bead | 6b. Taping/Removing Tape | 6c. Smoothing the Bead with Tool

6d. Filling Perimeter with Backer Rod | 6e. Smoothing the Bead with Wet Finger | 6f. Screwing

Figure 6. Finishing jobs

III. RESULTS

On each observation day, at the end of each 60 seconds, a picture was taken, and note related to that picture was recorded. Notes were specified with a time, date, location, operation, and tasks. All images and their related notes were examined one by one and the PATH data collection survey was filled in for a picture(s) in Qualtrics software (Qualtrics XM; Qualtrics, 2018). A total number of 19,300 PATH surveys were completed. CGG workers' ergonomics evaluation using the PATH method was discussed in another paper but a small portion of the PATH results, CGG task activities, were used in this paper. Table 2 shows the percentage of time that workers spent in different operations performing different tasks and related activities. Data were imported into the software and the percentage of work time spent in the various task was determined.

3.1. CGG TASKS ACTIVITIES

CGG workers were observed mostly performing glass and panel installation tasks. MMH had the highest number of observations followed by hold activity for frame installation, glass/panel installation, and loading/unloading tasks. Applying/pushing the caulk bead and taping/removing tape were the activities with the highest number of observations for the finishing jobs (Table 2).

Table 2. Distribution of observations among construction glass and glazing job tasks

General Tasks	Job Specific Tasks			
Tasks Frequency: 20266	Frame Installation (FI) Frequency: 4666	Glass/Panel Installation (GPI) Frequency: 7539	Finishing Jobs (FJ) Frequency: 3802	Load/Unload (L/U) Frequency: 2059
General Tasks Activities (Frequency)	FI Activities (Frequency)	GPI Activities (Frequency)	FJ Activities (Frequency)	L/U Activities (Frequency)
▪Watch/Wait/Idle (3829) ▪Walk (2682) ▪Hold: Steady/Maintain (2066) ▪Communicate/ supervise (1960) ▪Operate lift (994) ▪Reach (680) ▪Monitor (591) ▪Fasten/Unfasten (195) ▪Housekeeping (175) ▪Read blueprint/ instruction (166) ▪Climb/Descend (142) ▪Harness on/off (60) ▪Gloves on/off (54) ▪Point/Direct (44) ▪Hold: Steady/Maintain resting on shoes (36) ▪Attach/detach land yard (32) ▪Rest (23) ▪Drive truck/lift (6) ▪No general activity & Btw & Not Sure (6531)	▪MMH (441) ▪Hold (267) ▪Screw/Unscrew (214) ▪Caulk (144) ▪Shim (134) ▪Drill (105) ▪Cut (89) ▪Measure (77) ▪Temporary mullion tie/untie to a column (66) ▪Hammer (65) ▪Level (58) ▪Attach/Remove Clamp (55) ▪Clean/Wipe (46) ▪Snap frames (Storefront) (44) ▪Mark (29) ▪Put vinyl/gasket (21) ▪No task specific activity & Btw& Not sure (2811)	▪MMH (1301) ▪Hold (736) ▪Screw/Unscrew (172) ▪Finishing job (caulk, tape, fill) (134) ▪Attach/Detach suction cups (130) ▪Pinch and pull cover (129) ▪Shim (118) ▪Put vinyl/gasket (116) ▪Clean/Wipe (111) ▪Measure and mark (92) ▪Level (64) ▪Drill (62) ▪Cut and grind (43) ▪Hammer (41) ▪Place temporary retainer clips (Curtainwall) (7) ▪No task specific activity & Btw & Not sure (4283)	▪Apply/Push the caulk bead (405) ▪Tape/Remove tape (314) ▪Smooth the bead of caulking with a finishing tool (283) ▪Clean/Wipe (272) ▪Put vinyl/gasket (237) ▪Fill the perimeter with backer rod (117) ▪Screw/Unscrew (116) ▪Smooth the bead of caulking with a wet finger (116) ▪Hammer (46) ▪Cut (38) ▪Spray (glass cleaner) (14) ▪Level (1) ▪No task specific activity & Btw & Not sure (843)	▪MMH (592) ▪Hold Glass (252) ▪Attach/Detach suction cups (118) ▪Open Glass Box (46) ▪Clean/Wipe (10) ▪Hammer (3) ▪Screw/Unscrew (2) ▪Measure (1) ▪Cut (1) ▪No task specific activity & Btw & Not sure (1034)

3.2. POSTURE ANALYSED

The decision regarding which posture to analyse was based on one or more criteria such as (i) the most frequent posture utilized, (ii) the posture maintained the longest in the working cycle, (iii) the posture that requires the greatest physical effort, (iv) the posture that causes the most discomfort, or (v) the most extreme posture, especially if it requires the application of force [8]. For each task, activities with higher observation percentage (frequent) and difficulty were chosen to calculate REBA scores. A total of 791 postures were selected to calculate the REBA scores; for each activity, several pictures were selected to cover all possible postures used for the activity. Different numbers of pictures were analysed for different tasks to cover all possible postures to perform tasks. Table 3 presents selected activities, percentages, and numbers of postures analysed for each CGG task. Percentages were calculated using the frequency of activities in Table 2 and calculated using MS Excel (Version 16; Office, 2016).

Table 3. CGG activities, percentages, and number of postures analysed for each task

Task	Activity	Percentage (including No task-specific activity & Between & Not sure)	Percentage (except for No task-specific activity & Between & Not sure)	Number of Posture Analysed
Frame Installation	Manual Materials Handling (MMH)	9.5 %	23.8 %	51
	Screw/Unscrew/Drill	4.6 %	11.5 %	70
	Caulk	3.1 %	7.8 %	37
	Shim	2.9 %	7.2 %	22
Glass/Panel Installation	MMH	17.3 %	40 %	128
	Screw/Unscrew/Drill	2.3 %	5.3 %	49
	Attach/Detach suction cups	1.7 %	4.0 %	14
	Pinch/Pull cover	1.7 %	4.0 %	14
	Shim	1.6 %	3.6 %	6
	Put vinyl/gasket	1.5 %	3.6 %	34
Finishing Jobs	Apply/Push the caulk bead	10.7 %	20.7 %	78
	Tape/Remove tape	8.3 %	16.0 %	33
	Smooth the bead of caulking with a finishing tool	7.4 %	14.5 %	37
	Fill the perimeter with backer rod	3.1 %	6.0 %	27
	Smooth the bead with a wet finger	3.1 %	5.9 %	7
	Screw/Unscrew	3.1 %	5.9 %	28
Loading/Unloading	MMH	28.8 %	57.8 %	75
	Attach/Detach suction cups	5.7 %	11.5 %	11
General Tasks	Hold	10.2 %	20.9 %	29
	Operate lift	4.9 %	10.1 %	29
	Fasten/Unfasten	1 %	2.0 %	12
			Total	791

3.3. RISK LEVEL OF WRMSDS OBTAINED FOR THE CGG TASKS

The work tasks were evaluated by calculating the REBA score for each task. REBA scores for tasks with a "medium", "high", and "very high-risk" levels were identified to determine the appropriate action levels. Data collected from the REBA method were statistically analysed using MS Excel (Version 16; Office, 2016). Each picture represented a possible posture for a selected activity of a task. A score for each posture was assigned using REBA tables and figures. The final score for each activity consisted of an average of the scores of the different postures analysed, and the final score of each task consisted of an average of the scores of the different activities calculated. Table 4 is an example of the REBA score calculation using MS Excel (Version 16; Office, 2016). The REBA method only applied to one side (left or right) if only one of the upper limbs was in an awkward posture. Calculation of REBA scores, the risk level of each CGG task, and the resulting recommended action was determined using the REBA action levels table (Table 1). REBA final score can range from 1 to 15 (non-existent risk to very high risk), where the final score is then used to determine the magnitude and priority of the measures to be taken for the most physically stressful tasks. The higher the final score obtained, the greater the WRMSDs risk associated with the task, and the greater the urgency to undertake a more detailed study of the activity and the workplace to implement possible changes [8]. Table 5 shows the results associated with REBA scores for different CGG tasks and their most frequent activities.

Table 4. REBA score calculation for frame installation task, shim activity using excel

<table>
<tr><td rowspan="14">CGG Frame Installation - Shim</td><td colspan="2">Posture No.</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">3</td><td colspan="2">4</td><td colspan="2">5</td><td colspan="2">6</td><td colspan="2">7</td><td colspan="2">8</td><td colspan="2">9</td><td colspan="2">10</td><td colspan="2">11</td><td colspan="2">12</td><td colspan="2">13</td><td colspan="2">14</td><td colspan="2">15</td><td colspan="2">16</td><td colspan="2">17</td><td colspan="2">18</td><td colspan="2">19</td><td colspan="2">20</td><td colspan="2">21</td><td colspan="2">22</td></tr>
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<tr><td>Load/Force</td><td>Coupling</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Score A</td><td>Score B</td><td>8</td><td>5</td><td>4</td><td>6</td><td>3</td><td>8</td><td>4</td><td>8</td><td>6</td><td>8</td><td>2</td><td>7</td><td>1</td><td>8</td><td>3</td><td>8</td><td>4</td><td>8</td><td>3</td><td>5</td><td>4</td><td>6</td><td>4</td><td>8</td><td>5</td><td>9</td><td>5</td><td>8</td><td>4</td><td>8</td><td>5</td><td>9</td><td>4</td><td>8</td><td>1</td><td>5</td><td>4</td><td>7</td><td>3</td><td>8</td><td>5</td><td>8</td><td>4</td><td>8</td></tr>
<tr><td colspan="2">Score C - Table C</td><td colspan="2">10</td><td colspan="2">6</td><td colspan="2">7</td><td colspan="2">8</td><td colspan="2">9</td><td colspan="2">5</td><td colspan="2">5</td><td colspan="2">7</td><td colspan="2">8</td><td colspan="2">4</td><td colspan="2">6</td><td colspan="2">8</td><td colspan="2">9</td><td colspan="2">8</td><td colspan="2">8</td><td colspan="2">9</td><td colspan="2">8</td><td colspan="2">3</td><td colspan="2">7</td><td colspan="2">7</td><td colspan="2">8</td><td colspan="2">8</td></tr>
<tr><td colspan="2">Activity Score</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td></tr>
<tr><td colspan="2">REBA Score</td><td colspan="2">11</td><td colspan="2">7</td><td colspan="2">8</td><td colspan="2">9</td><td colspan="2">10</td><td colspan="2">6</td><td colspan="2">6</td><td colspan="2">8</td><td colspan="2">9</td><td colspan="2">5</td><td colspan="2">7</td><td colspan="2">9</td><td colspan="2">10</td><td colspan="2">9</td><td colspan="2">9</td><td colspan="2">10</td><td colspan="2">9</td><td colspan="2">4</td><td colspan="2">8</td><td colspan="2">8</td><td colspan="2">9</td><td colspan="2">9</td></tr>
<tr><td colspan="2">Average REBA Score</td><td colspan="44">8.18</td></tr>
</table>

Table 5. Risk level of WRMSDs obtained for the construction glass and glazing tasks

Task	Activity	REBA Score	Risk Level	Action
Frame Installation	MMH	8.8	High	Necessary soon
	Screw, Unscrew, and Drill	7.2	Medium	Necessary
	Caulk	6.3	Medium	Necessary
	Shim	7.2	Medium	Necessary soon
Glass and Panel Installation	MMH	8.5	High	Necessary soon
	Screw, Unscrew, and Drill	5.5	Medium	Necessary
	Pinch and pull cover	3.9	Medium	Necessary
	Shim	4.3	Medium	Necessary
	Put vinyl/gasket	4.7	Medium	Necessary
	Attach/Detach suction cups	5.1	Medium	Necessary
Finishing Jobs	Apply/Push the caulk bead	5.6	Medium	Necessary
	Fill the perimeter with backer rod	4.9	Medium	Necessary
	Smooth the bead of caulking with a finishing tool	5.4	Medium	Necessary
	Smooth the bead with a wet finger	6.0	Medium	Necessary
	Tape/Remove tape	6.2	Medium	Necessary
	Screw/Unscrew	4.8	Medium	Necessary
Loading /Unloading	MMH	7.5	High	Necessary soon
	Attach/Detach suction cups	5.5	Medium	Necessary
General	Operate lift	2.1	Low	May be necessary
	Fasten/Unfasten	2.5	Low	May be necessary
	Hold	3.4	Low	May be necessary

3.3.1. Frame Installation Task

REBA scores of frame installation activities ranged between 6 and 9 corresponding to a medium and high WRMSDs risk level. "MMH" activity obtained the highest REBA score of 8.8 (Table 5) corresponding to a high WRMSDs risk level; this refers to a REBA action level of 3 (Table 1) that is necessary soon to further assess this task with the aim of reducing the risk level. Shim, screw/unscrew/drill, and caulk activities got REBA scores of 7.2, 7.2, and 6.3 respectively (Table 5), which refer to REBA action level of 2 (Table 1), indicating a medium risk of injury to the CGG workers and action level of 2 (necessary). Trunk posture (bend and twist), upper arm posture (at/above shoulder height), and load/force score were the contributory factors to the high and medium scores.

3.3.2. Glass/Panel Installation Task

REBA scores of glass/panel installation activities ranged between 4 and 9 corresponding to a medium and high WRMSDs risk level. The "MMH" activity REBA score was 8.5 (Table 5), this refers to a REBA action level of 3 (Table 1), indicating a high risk of injury to the CGG workers and that action

is necessary soon to further assess this task with the aim of reducing the risk level. Screw/unscrew/drill activity ranked number two with a REBA score of 5.5 followed by attach/detach suction cup, put vinyl/gasket, shim, and pinch/pull cover activities (5.1, 4.7, 4.3, and 3.9 respectively) (Table 5) corresponding to a medium risk level that shows necessary action level is required. Trunk posture (bend and twist), upper arm posture (at/above shoulder height), and load/force score were the contributory factors to the high and medium scores.

3.3.3. Finishing Jobs Task

REBA scores of finishing jobs activities ranged between 5 and 6 corresponding to a medium WRMSDs risk level. Tape/remove tape activity ranked number one with a REBA score of 6.2 followed by "smooth the bead with a wet finger", "apply/push the caulk bead", "smooth the bead of caulking with a finishing tool", "fill the perimeter with the backer rod", and "screw/unscrew/drill" activities (6, 5.6, 5.4, 4.9, and 4.8 respectively) (Table 5) corresponding to a medium risk level that shows the "necessary" action level is required (Table 1). Upper arm posture (at/above shoulder height), wrist posture, and neck posture were the contributory factors to the medium REBA scores.

3.3.4. Loading and Unloading Task

REBA scores of loading and unloading activities ranged between 5 and 8 corresponding to a medium and high WRMSDs risk level. The manual materials handling activity REBA score was 7.5 (Table 5) that refers to a REBA action level of 3 (Table 1), indicating a high risk of injury to the CGG workers and that action is necessary soon to further assess this task with the aim of reducing the risk level. Trunk posture (bend and twist), upper arm posture (at/above shoulder height), and load/force score were the contributory factors to the high REBA score.

3.3.5. Loading and Unloading Task

REBA scores for "hold", "fasten/unfasten", and "operate lift" activities ranged between 2 and 3 (Table 5) corresponding to a low WRMSDs risk level with the action level of "may be necessary" (Table 1).

IV. CONCLUSIONS AND DISCUSSION

The REBA method was applied to scale the CGG workers' level of risk of developing musculoskeletal injuries. Real-life data were collected that represent CGG real life on a job site by using an observational method that did not interfere with glazing job tasks.

The method results in a final score that can range from 1 to 15 (non-existent risk to very high risk) and indicates the magnitude and priority of the measures to be taken. The REBA method relies on subjective observational method assessments to estimate the risk of associated WRMSDs for specific job tasks.

MMH activity obtained the highest REBA score with a high risk-level for frame installation, glass/panel installation, and loading/unloading tasks (8.8, 8.5, and 7.5 respectively). Trunk posture (bend and twist), upper arm posture (at/above shoulder height), and load/force score were the contributory factors to the highest REBA score. An ergonomics intervention to reduce MMH is the usage of power cups/robots or other lifting machinery such as carts and trolleys to lift, carry, and set up heavy/big glasses if possible. Screwing/unscrewing/drilling, and caulking activities were among activities with a medium WRMSDs risk level that refers to a REBA action level of 2 (necessary). Trunk posture (bend and twist), upper arm posture (at/above shoulder height), and load/force score were the contributory factors to the medium score. Better pre-fabrication assembly design that requires significantly less overhead drilling, screwing, holding a posture, and force application could be an intervention to reduce ergonomics exposures. Regarding the "caulk" activity, improved caulking gun tips that do not require finger spreading or tooling knife spreading following caulking bead application is a potential intervention to be considered.

The research is a limited scale "pilot project" in Nebraska and therefore it is not possible to generalize the results of this study to the rest of the United States. The recruitment process was a challenge and it took more time than expected. Although the research team could convince companies by holding

introduction sessions, some of the targeted companies did not participate because they were afraid of losing working time. Cold weather was another challenge during data collection. Besides losing time to observe due to weather conditions, electronic devices such as Google Glass and observer's smartphone were running out of charge due to the cold weather. It was also difficult taking notes while wearing gloves. Other ergonomics exposures may arise during hot weather that may affect the incident rates of injuries/illnesses among CGG workers. Future studies can focus on ergonomics interventions performing MMH or screwing/unscrewing/drilling activities of CGG work. A work-sampling approach such as REBA can be used to evaluate whether future interventions are successful in reducing the rate of musculoskeletal risk factors.

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APPENDIX A

Table 6. Group A Scores Adopted from Hignett and McAtamney [19]

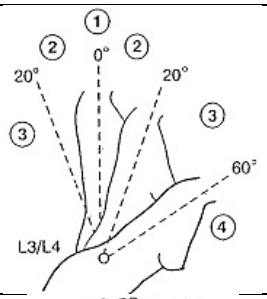
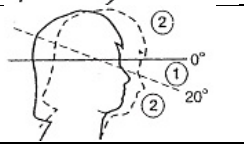
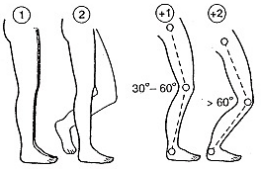
Body Part	Movement/Position	Score	Add to Score	Postures
Trunk	Upright	1	+1 if twisting or side flexed	
	0˚- 20˚Flexion 0˚- 20˚Extension	2		
	20˚- 60˚Flexion > 20˚Extension	3		
	> 60˚Flexion	4		
Neck	0˚- 20˚Flexion	1	+1 if twisting or side flexed	
	> 20˚Flexion or in extension	2		
Legs	Bilateral weight bearing, walking or sitting	1	+1 if knee(s) between 30˚and 60˚flexion	
	Unilateral weight bearing Feather weight bearing or an unstable posture	2	+2 if knee(s)> 60˚ flexion (Not for sitting)	

Table 7. Table A Adopted from Hignett and McAtamney [19]

Trunk		Neck											
		1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
1		1	2	3	4	1	2	3	4	3	3	5	6
2		2	3	4	5	3	4	5	6	4	5	6	7
3		2	4	5	6	4	5	6	7	5	6	7	8
4		3	5	6	7	5	6	7	8	6	7	8	9
5		4	6	7	8	6	7	8	9	7	8	9	9

Table 8. Load/Force Score Adopted from Hignett and McAtamney [19]

0	1	2	+1
< 5 kg	5 -10 kg	> 10 kg	Shock or rapid buildup of force

APPENDIX B

Table 9. Group B Scores Adopted from Hignett and McAtamney [19]

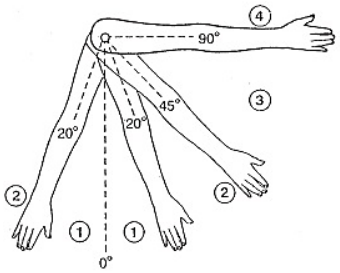
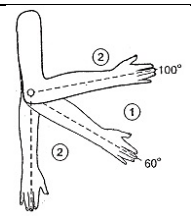
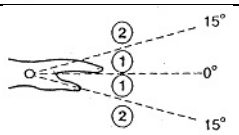
Body Part	Movement/Position	Score	Add to Score	Postures
Upper Arms	20˚extension to 20˚ flexion	1	+1 if arm is: • abducted • rotated +1 if shoulder is raised -1 if leaning, supporting weight of arm or if posture is gravity assisted	
	> 20˚extension 20˚-45˚flexion	2		
	45˚-60˚flexion	3		
	> 90˚flexion	4		
Lower Arms	60˚-100˚flexion	1		
	< 60˚flexion or > 100˚ flexion	2		
Wrists	0˚-15˚ flexion/extension	1	+1 if wrist is deviated or twisted	
	> 15˚ flexion/extension	2		

Table 10. Table B Adopted from Hignett and McAtamney [19]

Upper arm	Lower arm					
	1			2		
Wrist	1	2	3	1	2	3
1	1	2	2	1	2	3
2	1	2	3	2	3	4
3	3	4	5	4	5	5
4	4	5	5	5	6	7
5	6	7	8	7	8	8
6	7	8	8	8	9	9

Table 11. Coupling Adopted from Hignett and McAtamney [19]

0	1	2	3
Good	Fair	Poor	Unacceptable
Well-fitting handle and a mid-range, power grip	Hand hold acceptable but not ideal or coupling is acceptable via another part of the body	Hand hold not acceptable although possible	Awkward, unsafe grip, no handles Coupling is unacceptable using other parts of the body

APPENDIX C

Table 12. Table C Adopted from Hignett and McAtamney [19]

	Score B												
Score A		1	2	3	4	5	6	7	8	9	10	11	12
	1	1	1	1	2	3	3	4	5	6	7	7	7
	2	1	2	2	3	4	4	5	6	6	7	7	8
	3	2	3	3	3	4	5	6	7	7	8	8	8
	4	3	4	4	4	5	6	7	8	8	9	9	9
	5	4	4	4	5	6	7	8	8	9	9	9	9
	6	6	6	6	7	8	8	9	9	10	10	10	10
	7	7	7	7	8	9	9	9	10	10	11	11	11
	8	8	8	8	9	10	10	10	10	10	11	11	11
	9	9	9	9	10	10	10	11	11	11	12	12	12
	10	10	10	10	11	11	11	11	12	12	12	12	12
	11	11	11	11	11	12	12	12	12	12	12	12	12
	12	12	12	12	12	12	12	12	12	12	12	12	12

Table 13. Activity Score Adopted from Hignett and McAtamney [19]

+ 1	1 or more body parts are static, e.g. held for longer than 1 min
+ 1	Repeated small range actions, e.g. repeated more than 4 times per minute (not including walking)
+ 1	Action causes rapid large range changes in postures or an unstable base