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Analysis on the Work-Related Musculoskeletal Disorders (WMSD's) Based on Ergonomic Study in Case of Industry Study

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Abstract —Musculoskeletal disorders (MSDs) can affect the body's muscles, joints, tendons, ligaments and nerves. Most work-related MSDs develop over time and are caused either by the work itself or by the employees' working environment. The paper presents a case study on the analysis of the Work-related musculoskeletal disorders (WMSD's) occur when there is a mismatch between the requirements of the job and the physical capacity of the human body. Risk factors linked with WMSD's include repetitive motion, heavy lifting, forceful exertion, awkward posture, and rapid hand and wrist motion. In a review of loss-based data (1993), ergonomic-related injuries are the single greatest source of lost-time in the workplace today. Currently, these injuries account for between 33% and 40% of total worker compensation spending. This statistics compiled by the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH).

Keywords— Musculoskeletal disorders (MSDs), Work-related musculoskeletal disorders (WMSD's), Occupational Safety and Health Administration (OSHA), National Institute for Occupational Safety and Health (NIOSH).

1. INTRODUCTION

In a review of loss-based data (1993), ergonomic-related injuries are the single greatest source of lost-time in the workplace today. Currently, these injuries account for between 33% and 40% of total worker compensation spending. As the work force ages and healthcare cost continue to rise, these percentages are expected to hit 50% by the end of the century. The study has been conducted at small medium industry (SME) is in the beverage industry where it produces, bottles, and distributes a variety of products. The Bottle House Department of contains a de-palletizing workstation, which is the starting point of the bottling process. Employees at this workstation are complaining of physical distress that may be associated with exposure to the potential material handling-based risk factors as they manually unload pallets of new cases of bottles from a pallet to a conveyor. Consequently, 8 employee complaints of lower back or elbow pain indicate that ergonomic risk factors may exist at the de-palletizing workstation.

This company is in the beverage industry producing, bottling, and distributing a variety of products. The starting point of the bottling process begins at the de-palletizing workstation where employees manually
unload new cases of bottles from a pallet onto a conveyor. Workers at this station were complaining of discomfort in the shoulders, neck, elbows, hands, wrists, and lower back from excessive overhead reaching at the beginning of a new pallet and forward bending toward the end of the unloading process.

2. BACKGROUND AND SIGNIFICANT

According to the National Occupational Research Agenda, lower back pain is one of the most common and significant musculoskeletal problems in the world. Thirty percent of American workers are employed in jobs that routinely require them to perform activities that may increase risk of developing low back disorders. The Occupational Safety and Health Administration reports over one million workers each year are affected by back pain. Economically, lower back disorders in the United States cost between $50 and $100 billion each year. An estimated $11 billion of those costs are covered by worker compensation, with an average back injury claim costing the employer $8,300, which is more than twice the average cost of all other types of compensable claims combined (NORA). Lower back and elbow pain complaints from employees have alerted upper management that ergonomic risk factors may be present. If a WMSD injury occurs, the company will have direct costs including medical and indemnity payments as well as indirect costs such as paying overtime, decreased employee morale, lost production, or missed production schedules, etc. The company has recognized that the de-palletizing workstation may pose extraordinary ergonomic risk factors. Therefore, the company prefers to reduce or eliminate the potential risk factors before the employees become symptomatic. The purpose of this study is to identify, via ergonomic assessment, if workstation design and work practice risk factors are currently exposing employees to injuries and illnesses at company's de-palletizing workstation.

The goals of this study include:

- Identify to what extent that employees are suffering from WMSD symptoms.
- Analyze and quantify the extent that ergonomic risk factors may be present at de-palletizing workstation.

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3. ASSUMPTIONS AND ASSESSMENT

Assumptions made for this study include:

- The employees at case study industry are earnest in their complaints about back and elbow pain they are experiencing from the de-palletizing workstation
- The employees at case study industry fill out the WMSD Signs and Symptom Surveys with integrity and without bias
- The employees at case study industry perform consistently the methods and practices they use to de-palletize while the workstation is being videotaped.

The purpose of this study was to identify, via ergonomic assessment, if workstation design and work practice risk factors were exposing employees to injuries and illnesses at case study Company's de-palletizing workstation. This ergonomic assessment was performed in three steps. First, the researcher began by identifying the extent of the 3 employees discomfort by utilizing work-related musculoskeletal disorder symptom surveys. These results indicated the severity and location of the employee's distress and informed the researcher of the extent of the problem. In the second step, the researcher video-recorded an employee's bodily postures while performing job duties at the de-palletizing workstation. The body angles and posture measurements were incorporated into three ergonomic methodologies to reveal the severity and amount of intervention required by company. The results from the symptom surveys and products of the methodologies revealed that the de-palletizing workstation is in fact exposing the employee's to risk factors that lead to the onset of work-related musculoskeletal disorders (WMSD's). The final step in this process was to recommend suitable engineering controls that will reduce or eliminate those risk factors, while protecting and preserving employees and preventing future worker compensation expenditures.

4. DATA COLLECTION AND ANALYSIS

Once the Super-8 video recorder is positioned, the researcher will count the number of individual cases, measure its height, width, and weight and then determine the overall dimensions of one full pallet. The researcher and subject can begin video recording.

During the taping session, some data needs to be collected on-site to complete the NIOSH Lifting Equation. Measurements for the horizontal, vertical, and distance multipliers will be made with a conventional tape measure, while the asymmetric value will be projected with the goniometric. The hand to-object interface (coupling) of the cases and subject will be rated according to the NIOSH Lifting Equation criteria. The researcher will also be timing the lifts per minute for the frequency multiplier of the NIOSH Lifting Equation 48 and the repetition criteria for the R.U.L.A. and BRIEF Survey. Another component of the NIOSH Lifting Equation is the conveyor (destination) height which will be measured and documented. Any additional observations made regarding workstation design, safe work practices, and environmental concerns will be documented and taken into consideration while analyzing the data. Data analysis will be completed in several steps. First, the researcher will review the symptom surveys to reveal if the employees are indeed experiencing any pain or discomfort from working at the de-palletizing station. The surveys will identify the symptom locations and to what extent the employees are feeling distress from potential WMSD risk factors. The main areas of concern are the lower back, the elbows (Epicondylitis), shoulders (TOS), and the wrists (CTS). This information will be charted in table form and expressed as a percentage of the population surveyed.

The second step will be to complete the R.U.L.A. and Brief Survey by utilizing the jog shuttle VCR, goniometric, and a water-based felt tip marker. This instrumentation will allow the researcher to analyze the subject's postures frame-by-frame as they unload the pallet of cases. The felt tip marker will allow the researcher to draw lines on the television screen to assist in measuring the body postures and joint angles with the goniometric. Specifically, the researcher will be looking for the most severe instances of flexions/extensions and ulnar/radial deviations of the hands and wrists, pronation / supination of the forearms and elbows, shoulder abduction/adduction, trunk twisting, forward bending, and feet location and support. Observations for the more severe postures and joint angles will be made while the employee is unloading the top, 49 middle, and bottom layers of the pallet. For example, the first section of group A in the R.U.L.A. examines as to what degree the shoulders are raised and/or abducted. The researcher will be able to extract those measurements needed through a thorough examination of the video recording and correlate the results with the criteria in the R.U.L.A. or the Brief Survey. The product of the R.U.L.A. is a grand score, while the results of the BRIEF Survey are in the form of a high-risk summary.

The NIOSH Lifting Equation is the third step in this analysis. All the data that was collected during the taping session will be incorporated into the Recommended Wight Limit (RWL) equation yielding the RWL. Furthermore, the RWL will be included in the Lifting Index (LI) equation to calculate the LI score that will be used to determine the severity and the amount of intervention required to reduce the risk factors that contribute to the onset of WMSD's.

At the conclusion of the data collection process, the information extracted from methodologies and symptom surveys will be used by the researcher to compare and contrast the similarities, dissimilarities, and interpret the final results. In combination, these ergonomic assessment tools will assist the researcher in determining whether or not the

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employees at case study industry are being exposed to WMSD risk factors at the de-palletizing workstation.

5. ERGONOMIC RISK ASSESSMENT

The employees at de-palletizing workstation are unloading pallets of beverage cases that contain 24 new bottles per case at an average rate of 18 cases per minute. One pallet consists of one hundred and eight cases that weigh 12.02 pounds each. The dimensions for an individual case (figure 1) and the overall dimensions of one full pallet are illustrated in Figure 1.

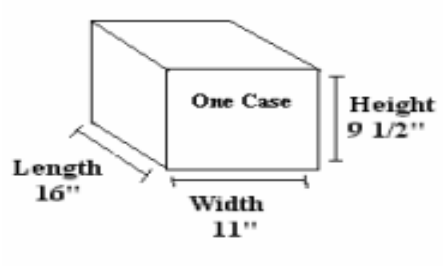

Figure 1: Case Dimensions

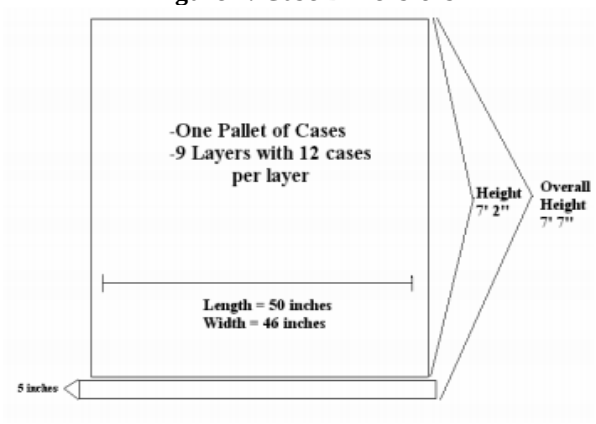

Figure 2: Pallet Dimensions

The employees at this workstation have to extend their reach over seven feet to remove the top layer of cases from a pallet. As the pallet is unloaded, the employees at this station have to bend forward and reach down to pick up the last row of cases and place them on a conveyor that's approximately 32 1/2 inches off the ground. The repetitive and awkward postures of this nature are what the employees at the de-palletizing workstation have to deal with on a daily basis. More information on the employees who work at the de-palletizing workstation and the results of the symptom surveys are in the next sections.

A. Demographic Information

The workstations has on average has 10 employees on two shifts that rotate in and out of the de-palletizing workstation every half hour. Of those, six people agreed to participate in the study by filling out the symptom surveys, therefore representing 60% of the total possible participants. Of the six, two (33.3%) were female and the remaining 4 (66.7%) were male. Four (66.7%) of the six employees have been working at the de-palletizing workstation for one year or more, while the remaining 2 (33.3%) have less than one year at this position. The overall results of the symptom survey these employees filled out are discussed in the next section.

B. Symptom Survey Analysis

The symptom surveys revealed that all 6 employees participating in this study have in the last year experienced some type of discomfort from working at the de-palletizing station. Specifically, the areas of concern for this study included the lower back, elbows/forearms, shoulders/neck, hands and wrists. The areas of discomfort for each of the six employees are charted in Table 1.

Table 1: Discomfort Locations

Employee	Shoulders / Neck	Lower Back	Elbows / Forearms	Hands /Wrists
1	X	---	X	---
2	X	X	X	X
3	X	---	---	---
4	X	X	---	---
5	X	X	X	---
6	---	X	---	X
Totals	5	4	3	2
Percentage	83.3	66.6	50	33.3

As indicated in Table 1, nearly 84% of the participants have encountered or are currently experiencing discomfort in the shoulder and neck region. Almost 67% have encountered lower back pain during their employment at this workstation. Discomfort in the elbows and forearms have affected or are currently inflicting pain on 50% of the employees, while 33% claim distress in the hands and wrists. Nearly all of the employees have attributed their aches and pains from the excessive amount of overhead reaching at the beginning of a new pallet and bending down to remove the last row of cases at the end of a pallet. The signs and locations of discomfort the participants specified in the symptom surveys are the same types of work-related musculoskeletal disorders. Several of the employee's claim that their discomfort includes pain, tingling, and numbness when sleeping, while the remainder of the participants state their discomfort arises in the form of stiffness, swelling, and a burning sensation in the affected areas. Evidence from the symptom surveys reveal that the de-palletizing workstation is exposing the employees to the potential risk factors that lead to the onset of WMSD's. In the next section the researcher will evaluate the results of the ergonomic analysis to better determine the causes of the problem

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C. Methodology Analysis

In conjunction with the symptom surveys, the researcher will use the results from the ergonomic methodologies to better determine the extent of the problem at de-palletizing workstation. The data extracted from the NIOSH Lifting Equation, Rapid Upper Limb Assessment (R.U.L.A.), and the Baseline Risk Identification of Ergonomic Factors (BRIEF Survey) will help the researcher determine the severity and amount of intervention required to eliminate the risk factors that lead to the onset of WMSD's.

D. NIOSH Lifting Equation

The NIOSH Lifting Equation is a methodology the researcher used in this study to help determine to what extent the employees are being exposed to WMSD risk factors. The lifting equation is comprised of two parts. The first is the Recommended Weight Limit (RWL) and the other is the Lifting Index (LI). The researcher will calculate and discuss the two components in the next section.

The NIOSH Lifting equation is expressed as:

RWL = LC x HM x VM x DM x AM x FM x CM (1)

The measurements required to complete this equation were taken during the data collection process. The measurements are documented in table 2.

Table 2: NIOSH Equation Components

Components	On-site Measurements	Calculations
Load Constant (LC)	51 pounds	51 pounds
Horizontal Multiplier(HM)	12"	0.83
Vertical Multiplier (VM)	14.5"	0.891
Distance Multiplier (DM)	18"	0.92
Asymmetric Multiplier (AM)	45°	0.856
Frequency Multiplier (FM)	Less than 1 hour	---
Coupling Multiplier (CM)	Poor	0.90

The RWL was calculated using the following equation of numbers.

RWL = 51 * .83 * .891 * .92 * .856 * .90
= 26.73 pounds
RWL = 26.73 pounds

NIOSH defines the RWL for a specific set of task conditions as the weight of the load that nearly all healthy workers could perform over a substantial period of time without an increased risk of developing lifting related lower back disorders. The RWL is then required to complete the LI equation, which can be utilized to estimate the relative magnitude of physical stress for a lifting task. The greater the LI score, the smaller the fraction of employees that are capable of safely sustaining that particular level of physical exertion. A Lifting Index score greater than 1.0 indicates a need for immediate attention, as the lifting task has the increased potential for accumulating WMSD's, especially lower back disorders. The Lifting Index formula is:

LI = Load Weight (L) / RWL
LI = 12.02 pounds (L) / 26.73 pounds (RWL)
LI = 0.45

The Lifting Index for the de-palletizing workstation is 0.45, which indicates there is very little need to intervene with the workstation. However, the results from this equation are not consistent with the symptom surveys and employee complaints. To obtain a better understanding of the extent the problem, the researcher will complete the Rapid Upper Limb Assessment.

E. Rapid Upper Limb Assessment (R.U.L.A)

R.U.L.A. is an ergonomic methodology that examines the postures of the upper extremities, trunk, and legs. The researcher used this methodology to capture the upper extremity angles on the subject as they unloaded one full pallet of cases. The next section will reveal the step-by-step results and the grand score.
The Rapid Upper Limb Assessment is divided into three sections, group A, group B, and a grand score table. The results for each of the groups and the grand score are presented in Table 3.

Table 3: R.U.L.A Score Sheet

Group A: *Arm and Wrist Analysis*	Score
Step 1: Upper Arm Position	5
Step 2: Lower Arm Position	1
Step 3: Wrist Position	3
Step 4: Wrist Twist	1
Step 5: Posture Score A	5
Step 6: Add Muscle Use Score	1
Step 7: Add Force / load Score	2
Step 8: Final Wrist / Arm Score	8

Group B: *Arm and Wrist Analysis*	Score
Step 9: Neck Position	4
Step 10: Trunk Position	5
Step 11: Leg	2
Step 12: Posture Score B	7
Step 13: Add Muscle Use Score	1
Step 14: Add Force / Load Score	2
Step 15: Final Neck, Trunk and Leg Score	10

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Table 4: Grand Score Table

Final Arm and Wrist Score = **8**

	1	**2**	**3**	**4**	**5**	**6**	**7+**
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	**7**

Grand Score = 7

Final Neck, Truck and Leg Score = **10**

Group A of the R.U.L.A. analyzed the arms and wrist postures. The angle criteria for each of the steps were scored according to the subject's postures on screen. Steps one and two located the degrees of upper and lower arm extensions, while three and four identified the amount of wrist flexion and twisting. The scores combined are utilized in table A of the R.U.L.A. to yield a posture score of five. The muscle use and force/load numbers are then added to the posture score to result in a final wrist and arm score of eight. The final wrist and arm score (8) is inputted into the grand score table.

Group B of the R.U.L.A. analyzed the neck, trunk, and leg positions. Steps nine, ten, and eleven measured the degrees of neck extension, bending and twisting of the trunk, and support from the legs, which yielded a posture B score of seven. Added to the seven, is the muscle use and force/load score to result in the final neck, trunk, and leg score of ten. The ten is incorporated into the grand score table to result in a final overall score of seven. Seven indicates the need for further investigation and immediate intervention at the workstation. Seven is the highest score allotted for this assessment therefore the results are significant.

The Baseline Risk Identification of Ergonomic Factors (BRIEF Survey) is another ergonomic methodology that examines the postures of the upper extremities, neck, back, and legs. This assessment process is similar to the R.U.L.A. method as it assists in determining the severity and amount of intervention required to reduce or eliminate the risk factors associated with WMSD's. The results of the BRIEF Survey will be discussed in the next section.

F. Result and Recommendation

The BRIEF Survey analyzes the posture, force, duration, and frequency for the left and right hands, wrists, elbows, and shoulders. It also examines the posture, force, duration, and frequency for the neck, back, and legs. The results for the applicable criteria for the BRIEF Survey are illustrated in Table 5. The posture analysis for the left and right hands and wrists indicated that the subject was using a pinch grip to grasp the cases and their wrist flexion was greater than 45 degrees. The force of the pinch grip was estimated at greater than two pounds, therefore scoring a two for the hand and wrist category. The posture rating for the elbows includes.

Table 5: High Risk Summary

High Risk Summary	
◀Hand / Wrist	◀Hand / Wrist
◀Elbow	◀Elbow
◀Shoulder	◀Shoulder
◀Neck	
◀Back	
◀Legs	

Each grouping has a total number score. If the number is two or greater, then the area of the body that's affected gets marked in the High Risk Summary Box. (Table 5) All of the body parts in this survey have been marked with a red triangle in the High Risk Summary Box. These results indicate the need for intervention with some type of controls to reduce/eliminate the WMSD risk factors. The R.U.L.A., BRIEF, and symptom surveys indicated significant potential for WMSD's at de-palletizing workstation. These results are consistent with the employee complaints that the excessive overhead reaching and awkward bending to pick up cases is the overall cause of their distress. In contrast, however, the NIOSH Lifting Equation did not indicate substantial problems in that the product of this methodology yielded a Lifting Index Score of only 0.45. A disadvantage of this equation 60 is that it only accounts for the perfect lifting tasks that are directly from the pallet or floor to the destination spot. The lifting tasks at this workstation often require employees to shuffle their feet or walk around the pallet to gain access to all sides of the pallet of cases. The NIOSH Lifting Equation is not applicable to those types of conditions. Whereas, the R.U.L.A. and Brief Survey measure the full body including the upper extremities, back, legs, and trunk.

The researcher's first recommendation is to fully automate the de-palletizing workstation. Alvey Systems, Inc. (Packexpo.com, 2002) manufactures the Accu-Flow De-palletized, which removes cases from the pallets and unscrambles them onto a single conveyor line. The Accu-Flow is capable of handling 3000 pounds with an output rate of up to seventy cases per minute. The benefits of this system are that it is 3-4 times faster than manual de-palletizing, reduces product damage, and eliminates the WMSD risk factors that currently cause the employees discomfort. Other benefits of the Accu-Flow De-palletized include built-in control functions such as oversized load protection and a complete diagnostics system in the event of a malfunction

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(Packexpo.com, 2002).

If the fore-mentioned recommendation is not feasible due to cost, space limitations, or applicability to the current process at case study industry, the researcher has provided a second recommendation. This option for engineering the risk factors out of the workstation involves a hydraulic lift table provided by Advance Lifts, Inc. (Avancelifts.com, 2002). This lift table has a fifteen hundred pound capacity and a travel distance of 96 inches. Currently, the overall pallet height is 91 inches. This lift table can be utilized by submerging it into the floor where the workstation currently exists. The de-palletized operator would be able to place the pallet on the lift table at floor level and then lower it 64 until the top layer is at roughly waist height on the employee. An additional option is adding an Advance Lift's work positioned (turn-table) to the hydraulic table. The benefit of adding the turn-table is that as employee unloads the layers of cases, the table can be raised and then rotated to keep the cases directly in front of them. The overall benefits of this system would include relieving the amount of awkward postures such as excessive overhead reaching and forward bending that is currently causing the distress the employee's are experiencing. Also, once the operators are familiar with using the lift table, this control could possibly reduce the amount of product loss and increase product output per minute.

Overall, the goal of utilizing the engineering controls is to reduce or eliminate the excessive reaching and bending associated with working at the current manual de-palletizing workstation. The employees are currently and will continue in the future to suffer discomfort in the upper extremities and lower back if the workstation design is not automated. The net effect of the above options would be to relieve the workers from risk factors that lead to the onset of WMSD's which plague the nation's industries today.

6. Conclusion

The combined results of the R.U.L.A., BRIEF, and symptom surveys reveal that de-palletizing workstation does expose the employees to the risk factors that lead to the onset of work-related musculoskeletal disorders. The scores for the R.U.L.A. and BRIEF Survey were as high as the methodologies would allow, which indicates the need for immediate intervention. The researcher has concluded the best way to reduce or eliminate the risk factors is by utilizing some form of engineering controls. The current workstation is inadequately designed, rendering safe work practices, personal protective equipment, and administrative controls that no applicable. Consequently, the best practice to eliminate the excessive overhead reaching 63 at the beginning of a new pallet and the forward bending when the pallet is nearly empty is to engineer the risk factors out of the workstation. In the next section, the researcher will provide some possible engineering controls to reduce or eliminate the risk factors that lead to the employee's distress.

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