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## Using Observations from the UAW-Ford Ergonomic Assessment Tool to Predict Low Back Musculoskeletal Disorders

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Using Observations from the UAW-Ford Ergonomic Assessment Tool to  
Predict Low Back Musculoskeletal Disorders

by

Colins Nwafor

A thesis submitted in partial fulfillment  
of the requirements for the degree of  
Master of Science in Public Health  
with a concentration in Occupational Exposure Science  
Department of Environmental and Occupational Health  
College of Public Health  
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## **LIST OF ABBREVIATIONS & ACRONYMS**

ACGIH	American Conference of Governmental Industrial Hygienists
AUC	Area Under the Curve
eLB	Experienced Low Back Pain
EST	Ergonomic Surveillance Tool
FTOV	First Time Occupational Visit
LBP	Low Back Pain
LI	Lifting Index
MaxLI	Maximum Lifting Index
MMH	Manual Material Handling
MSD	Musculoskeletal Disorder
NIOSH	National Institutes for Occupational Safety and Health
PCLI	Peak Composite Lifting Index
PLI	Peak Lifting Index
RNLE	Revised NIOSH Lifting Equation
ROC	Receiver Operating Characteristic
RWL	Recommended Weight Limit
TLV	Threshold Limit Value
UAW	United Auto Workers
USF	University of South Florida

## **ABSTRACT**

Musculoskeletal disorders of the low back are common injuries found in many work environments. Some of the risk factors that workers experience include the weight of object being lifted during a task, frequency, duration, posture, distance the object is lifted, how well the worker can grasp the object, and the degree to which the worker may have to twist and turn their body during a lift. There are many tools that have been developed that are used to assess risk of a worker developing low back pain. The purpose of this study is to determine if the UAW-Ford Ergonomic Surveillance Tool (EST) is a good predictor of low back pain.

The data analyzed in this thesis are from a study done at four automotive manufacturing plants. About 50 interviews were done at each plant to determine if workers had experienced low back pain and other musculoskeletal disorders. To be considered a case job, a worker had to have visited the plant clinic for experiencing low back pain on the job or through an interview of an operator on the job questioning if pain or discomfort affected their work, activities outside of work, or sleep. They were also asked whether or not they sought treatment because of it. Any job associated with an operator who made a clinic visit or exhibited other treatment seeking behavior was considered as a case job. Logistic regression was conducted on this data using the EST and it showed statistical significance when using the maximum lifting index to predict low back pain. The analysis revealed that the maximum lifting index can be used to predict low back pain in workers. A cut point for the maximum LI of 1.3 with a sensitivity of 0.96 and specificity of 0.89 will be good at determining if a job task is at an increased risk of low back pain.



## CHAPTER ONE: INTRODUCTION

Musculoskeletal disorders (MSDs) and the problems that come with them are not just a problem in the United States, they are a problem that is occurring around the world (Melhorn, 2014). It is an issue not just in the non-occupational setting but especially in the occupational setting. In 2018, the incidence of MSDs was 29.1 per 10,000 full-time workers (Bureau of Labor Statistics [BLS], 2020). Since a work-related injury only requires a complaint of the worker feeling pain, the whole event can be very subjective. These work-related MSDs are often challenging to deal with for occupational safety and health professionals and physicians treating these patients (Melhorn, 2014). It can require more tests, treatments, and studies being done to arrive at a diagnosis that would be similar to a patient with a non-occupational injury (Melhorn, 2014).

MSDs in particular low back pain (LBP) is a common health problem that many people in the world deal with (World Health Organization [WHO], 2003). In 2010, MSDs were responsible for about 29% of injuries and illness that had workers take days off from work and in nearly half of these cases, the cause was an injured back (BLS, 2011). These cases required a median of seven days to return to work (BLS, 2011). About 80 to 85% of people who are affected by it in their lives and it can cause limitations in the way people live their lives (WHO, 2003). In the National Health Interview Survey done in 2010 the self-reported prevalence of LBP in the past three months among workers was 25.7% (Yang et al., 2016). In the same year, the average claim cost for a back injury in Washington was \$8,467 (Washington Department of Labor & Industries, 2011). Proper ergonomic controls can help greatly reduce the injury to a

worker by creating and engineering a job to the worker. Guidelines and assessment tools have been created from epidemiological data, biomechanical and physiological data, psychophysical methodology in an attempt to reduce LBP that workers experience (Snook & Ciriello, 1991; Waters et al., 1994).

Occupational safety and health professionals need reliable ways of conducting exposure assessments for MSDs. It is difficult to determine a worker's current exposure to an MSD and even to accurately determine a worker's past exposure. In a 1997 criteria review done by NIOSH, it was found that many epidemiological research studies show that there is strong evidence that certain physical risk factors have strong causal relationships with MSDs when there is a combination of the risk factors or high levels of exposure (National Institute for Occupational Safety and Health, 1997).

To help protect workers from LBP, Liberty Mutual and the National Institute for Occupational Safety and Health (NIOSH) developed the Liberty Mutual Manual Material Handling Tables and the Revised NIOSH Lifting Equation (RNLE), respectively. The Liberty Mutual Manual Material Handling Tables provide population percentages for males and females that are able to different manual material handling tasks such as lifting, lowering, pushing, pulling, and carrying. The tables consider gender of the worker, frequency of the activity, hand and lift distance, and object weight to determine safe loads for manual handling. The NIOSH RNLE provides the Recommended Weight Limit (RWL). RWL is the weight of the load that most workers healthy workers can handled over a shift without an increased risk of LBP (Waters et al., 1994). These are two tools that are used when trying to prevent LBP. More research needs to be done to determine how well these tools work and how well they can predict the risk of LBP.

There are other tools that are used to assess a task that do not include duration as a factor and for this reason we should learn to understand how well these tools work and see if duration makes a difference. The purpose of this paper is to use data from the UAW-Ford Ergonomic Surveillance Tool (EST) to develop a predictor of LB disorders and to determine if there is a difference in reporting of LBP between working an eight-hour shift and a ten-hour shift.

## CHAPTER TWO: LITERATURE REVIEW

Ergonomics is simply the study of the relationship between a worker and their workplace. It can also be described as a multidisciplinary approach that looks to collect information about worker's capabilities and to use this information to help design the workplace and how jobs are done with different equipment (Eastman Kodak Company, Inc., 2004). Ergonomics is used to help improve productivity in the workplace and improving the health of the workers by making the task fit the worker's capability. The main goal for ergonomic is to prevent MSDs caused by exposure to awkward postures, excessive force, repetitive motions, etc. (Centers for Disease Control and Prevention, 2018).

Work-related MSDs occur when the requirements of a task do not match the worker's physical capabilities (Occupational Safety and Health Administration [OSHA], 2000). Physical risk factors for MSDs can be separated into seven major categories. Prolonged exposure to these risk factors can cause damage to a person's body and can lead to MSDs. The categories of risk factors that are most associated with work-related MSDs of the low back are weight, frequency, duration, posture, travel distance, coupling, and asymmetry. Coupling is the quality of the grasp of the object and the asymmetry angle is the degree of how much the object has been moved from the front of the worker either at the beginning or end of the lift. According to many studies excessive repetition, awkward postures, and heavy lifting are the most commonly reported biomechanical risk factors that show reasonable evidence for causing work-related MSDs (de Costa & Vieira, 2010). A study has shown that job physical risk factors are associated with increased risk of seeking care for LBP (Garg, Kapellusch, et al., 2014). This finding was

consistent with other studies that were done (Alexopoulos et al., 2006; Cote et al., 2005; IJzelenberg & Burdorf, 2004; Molano et al., 2001; Ozguler et al., 2000). Being exposed to one or a combination of any of these risk factors can cause problems or MSDs for the worker depending on the duration, frequency, and magnitude (OSHA, 2000).

Identifying risk factors and how they may create a hazardous exposure to an MSD for the worker for certain tasks may be relatively easy but for other jobs and tasks it will require different ergonomic assessment tools and equations to identify the other risk factors that are not as clear.

In ergonomics, breaking down a job into its many parts and tasks to look at and identify problems that are related to performing the task and control measures associated with the task are very important. The capacities and limitations of the worker to do a task and the design of the system have to be taken into consideration during an ergonomic assessment. The goal of an ergonomic assessment tool is to identify the risk factors in a task that make it troublesome and that expose a worker to an MSD. The information gathered with the tool can then be used to recommendations on redesign of a task if needed.

There are many tools that are used to analyze a task. They can evaluate risk quantitatively or qualitatively which can then be used to prioritize different controls that may be needed for a task, to identify training, and determine risk of injury. The most common among these tools is the revised NIOSH Lifting Equation (RNLE). Other tools that are used are the Liberty Mutual Manual Material Handling Tables also known as the Snook Tables.

The objective of the RNLE was to prevent or reduce the incidence of LBP among workers (Waters et al., 1994). It is a multiplicative model that helps to identify lifting tasks that may expose a worker to hazard. The equation includes seven components and each have a

multiplier that yields a Recommended Weight Limit (RWL). The seven components with multipliers are Load constant (LC), horizontal (HM), vertical (VM), distance (DM), asymmetrical (AM), frequency (FM), coupling (CM).

The equation is defined as  $RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$  (Waters et al., 1994). The RWL is will then be used in the Lifting Index (LI) equation which compares the weight of an actual load to the RWL. If the value that is determined from this equation for a task is greater than one, it implies there is a greater ergonomic risk (Waters et al., 1993; Waters et al., 1994).

The RNLE is a useful assessment tool to measure physical risk factors for LBP based on bio-mechanics, psychophysics, and physiology (Waters et al., 1993). It has been shown through previous studies that a LI or Composite Lifting Index (CLI) greater than one is associated with LBP (Lavender et al., 1999; Wang et al., 1998; Waters et al., 1999; Waters et al., 2011). However, these were cross-sectional studies and they cannot be used to establish a causal relationship between LI or CLI and LBP (Lu et al., 2014).

To help to determine this relationship between risk factors and work-related LBP, prospective studies were done recently to find a relationship between LI and CLI and LBP. The risk factors focused on in 13 studies assessing the risk exposure relationship between three assessment tools and LBP and their main findings are presented in Table A1. Every study included in Table A1, measured and determined that the weight of the object lifted is recognized as a risk factor that contributes to LBP. Frequency was another factor recognized by all but one of the studies as another risk factor. Six of the studies recognize that duration and coupling are risk factors of LBP. Ten of the studies have shown that horizontal location of the lift is a risk

factor and nine of these studies recognize that vertical location and travel distance of the lift are risk factors for LBP. Asymmetry was recognized as a risk factor by seven of these studies.

The LI and CLI included all of these factors and these studies help show that these metrics can be used to estimate risk of LBP. One prospective study came to this conclusion on this exposure-response relationship with significant evidence between Peak LI (PLI) and Peak CLI (PCLI) and LBP (Garg, Boda, et al, 2014). Two other prospective studies were done that found that PLI and PCLI are useful metrics to estimate the risk of medication use for LBP and seeking care for LBP (Kapellusch et al., 2014; Garg, Kapellusch, et al., 2014). One study did not find statistically significant evidence of an exposure-response relationship between these metrics and LBP but found that the trend in the relationship was positive (Lu et al., 2014). This study also found that workers with mean and maximum CLIs greater than 2.0 were significantly more likely to report LBP at one year of follow up compared to the workers with CLIs that were less than or equal to 1.0 (Lu et al., 2014). More research needs to be done to determine the predictability of CLI and LI for LBP.

The Snook Tables are a collection of data that were gathered from studies that were based on a psychophysical approach to the manual material handling (Snook, 1978; Snook & Ciriello, 1991). The data in these tables indicate the percent of the population capable of doing a certain manual material handling task without experiencing negative effects on the lower back. There are different tables for men and women that include lifting, lowering, carrying, pulling, and pushing. The tables provide weight values that were produced from realistic job tasks that were considered tolerable during experiments to a percentage of the population capable of doing the task (Snook, 1978; Snook & Ciriello, 1991). The tables consider the height of the lift at the

beginning and end, the force and the distance needed when carrying, pulling, and pushing, and frequency of the task.

Ergonomics looks to into the relationship between the worker and their work environment to find ways of improving the work environment by adjusting the worker's ability to improve comfort, increase productivity, and reduce injury. The purpose of this study was to determine if the maximum lifting index used in the UAW-Ford EST is predictive in a follow up study of automotive manufacturing in which the characteristics of the work have changed (more variability in job content and longer shifts).



## **CHAPTER THREE: METHODS**

University of South Florida (USF) investigators targeted about 50 jobs at each of four automotive manufacturing plants for review on the EST decisions and experience with first time occupational visits (FTOV) to seek healthcare for MSD. The goal was to obtain a broad profile of jobs with both Green and Red EST decisions and, independently, jobs with and without FTOVs. For those jobs with an FTOV history or a Red EST, there was an attempt to distribute these jobs evenly among the three body regions of distal upper extremities, low back, and neck/shoulder.

For data analysis, the outcomes were divided into cases for which the job was associated with at least one MSD and non-cases for which there was no association with MSDs. The principal independent variable was maximum lifting index.

### **Target Jobs**

Most of the target job selection effort occurred prior to the visit. First a list of FTOVs with an MSD flag was provided for the previous year (or longer if there was production stability; that is, no changes in models or model mix; and no changes in shift length). USF investigators then reviewed the descriptions of the incident. The incident was reviewed to confirm that it was due to the job requirements and that there were no extraordinary features (e.g., a worker slip/trip or malfunctioning equipment/parts). Then the incident was categorized as primarily an MSD at one of three body regions (neck/shoulder, distal upper extremity, or low back). The job associated with the FTOV was identified. Because it was essential to also have an EST for the job, the list of current ESTs was compared to the list of jobs identified with an FTOV. When it

was confirmed that an EST was available for the job or that an EST could be performed for that job, it became FTOV target job.

The next group of target jobs were those with an EST score of Red but no FTOV. These jobs were sorted by body region with Red flag and then randomly selected to sample for all three body regions.

Next, a selection of jobs with Green EST scores for all body regions was made. The absence of FTOVs was confirmed. These jobs were then randomly selected.

Finally, a group of jobs for which the Local Ergonomics Committee felt that there was little risk for an MSD were identified. It was confirmed that they had no FTOVs.

### **FTOV Jobs**

If there was an FTOV associated with a job, that was considered to be an FTOV job for outcome analysis.

### **Interviews**

The USF investigator interviewed an operator on each of the target jobs. No effort was made to match an FTOV to a specific operator, and it would be an unconfirmed coincidence if the FTOV operator and the interviewee were the same person.

A copy of the structured interview form is provided in Appendix 1. The interview confirmed that the operator (1) was willing to be interviewed and (2) was on the job for a month or more.

If the operator responded yes to both questions, the operator was asked if they experienced any muscle or joint pain in the past month that they would be willing to associate with that job. If they answered yes, then they were asked which body regions were affected.

For each body region they were asked two sets of questions. The first set asked if the pain or discomfort affected job performance, outside activities or sleep. The second set of questions asked about seeking healthcare treatment from the plant clinic, an outside provider, or a self-directed decision.

An interview was considered positive for an MSD if there was interference with work, play or sleep and treatment-seeking was from the clinic, from a private provider, or self-directed.

### **Outcome Status**

The primary outcome assigned to each job was

- Case: FTOV or Positive Interview
- Non-case: Neither an FTOV nor Positive Interview

### **EST Data**

The long form EST output was obtained for each job for which there was an interview and the FTOV status was known. The raw EST data for each job of was included in the database. The established rules for reducing the data to EST decision was followed through several steps that reduce the raw data into exposure metrics. Relevant to this study were the maximum lifting index, whether the job required lifting of more than 4 pounds, whether the job was associated primarily with standing or walking, and the shift length (8 or 10 hours).

### **Analysis**

Univariate analysis in the form of 2x2 tables was used to see if some of the job characteristics were associated with case jobs. The sensitivity and specificity were calculated.

Logistic regression was used to test the relationship between the combination of maximum lifting index (MaxLI) and manual material handling (MMH). This was also done to test the relationship of the combination of MaxLI and shift length (Shift) and the relationship

between MaxLI and eLB. The term “eLB” represents experienced low back pain. The equations tested were:

$$\text{Model 1: Logit (eLB)} = \alpha + \beta_1 \text{MaxLI} + \beta_2 \text{MMH}$$

$$\text{Model 2: Logit (eLB)} = \alpha + \beta_1 \text{MaxLI} + \beta_2 \text{Shift}$$

$$\text{Model 3: Logit (eLB)} = \alpha + \beta_1 \text{MaxLI}$$

Analysis of the data was done using the statistical software package JMP 15 from the Statistical Analysis Software Institute Inc.

## CHAPTER FOUR: RESULTS

A sample from four Ford plants was selected by UAW-Ford staff to represent the different work performed by the employees. The goal was to sample about 50 jobs in each plant. Table 1 reports the number of interviews and ESTs considered in the analysis. For BSP and CEP, there were some jobs selected for interviews for which an EST was not available; and this resulted in a higher number of interviews reported than ESTs. There were 202 job available for further analysis.

Table 1. Number of interviews and ESTs by plant and overall.

Plant	Interviews	ESTs
BSP (stamping)	50	48
CEP (engine)	57	52
DTP (assembly)	43	43
KTP (assembly)	59	59
All	209	202

First, the distribution of cases and non-cases for MMH (whether the job involved weights > 4 pounds), Standing (standing or walking for > 6 hours), and Shift (8 hours and 10 hours) were examined (see Tables 2, 3, 4, and 5). For MMH, a dichotomous outcome was based on 0 and 1. The dichotomous decision was 0 (not present) and 1 (present). This was also the same for Standing and Shift. Sensitivity and specificity were calculated for each table.

Table 2 is MMH, and the sensitivity was very high with good specificity. Table 3 is Standing, and the sensitivity is strong at 1.0 but has a very weak specificity. Table 4 is data

incorporating the presence of standing with MMH and this data analysis has a very high sensitivity and good specificity. Table 5 has a weak sensitivity and specificity.

Table 2. MMH vs. eLB

		eLB		Statistic	Value	95% CI
		No	Yes			
MMH	No	138	1	Sensitivity	0.96	0.81 to 0.99
	Yes	36	26	Specificity	0.79	0.73 to 0.85

Table 3. Standing vs. eLB

		eLB		Statistic	Value	95% CI
		0	0			
Standing	0	4	9	Sensitivity	1.0	0.87 to 1.0
	1	170	27	Specificity	0.0023	0.0063 to 0.0058

Table 4. MMH vs. eLB with Standing Excluded

		eLB			Statistic	Value	95% CI
		0, 0	1, 0	1, 1			
MMH	0	4	134	1	Sensitivity	0.96	0.81 to 0.99
	1	0	36	26	Specificity	0.79	0.72 to 0.85

Table 5. Shift vs. eLB

		eLB		Statistic	Value	95% CI
		0	1			
Shift	8	73	27	Sensitivity	0.00	0.00 to 12.77
	10	101	0	Specificity	0.42	0.35 to 0.50

In Model 1, MMH and MaxLI were modeled together and this showed that there was no statistical significance for MMH but MaxLI was significant at  $p = 0.0056$ .

Shift and MaxLI were modeled together in Model 2 and this analysis indicated that there was no statistical significance for Shift but MaxLI was significant at  $p = 0.0082$ . In the effect

likelihood ratio test, Shift and MaxLI were both statistically significant at  $p = 0.041$  and  $p = <0.0001$  respectively. The effect likelihood ratio test performed shows that Shift does play a significant role with LBP.

Model 3 was statistically significant with a  $p$  value of 0.005.

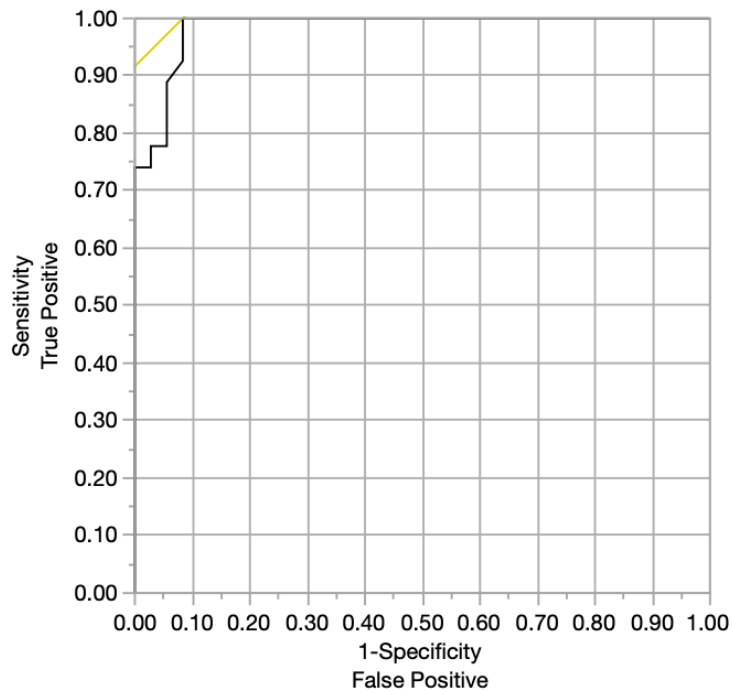


Figure 1. Receiver Operating Characteristic curve for MaxLI

The area under the curve (AUC) of the ROC was 0.98 which shows that this model has very good ability to distinguish between cases and non-cases. The  $p$  value from Model 3 supports this result that the MaxLI can be used to predict LBP.

Figure 2 is a plot of sensitivity and specificity against MaxLI. This plot displays a cut point at a MaxLI of 1.3 with a sensitivity of 0.96 and specificity of 0.89.

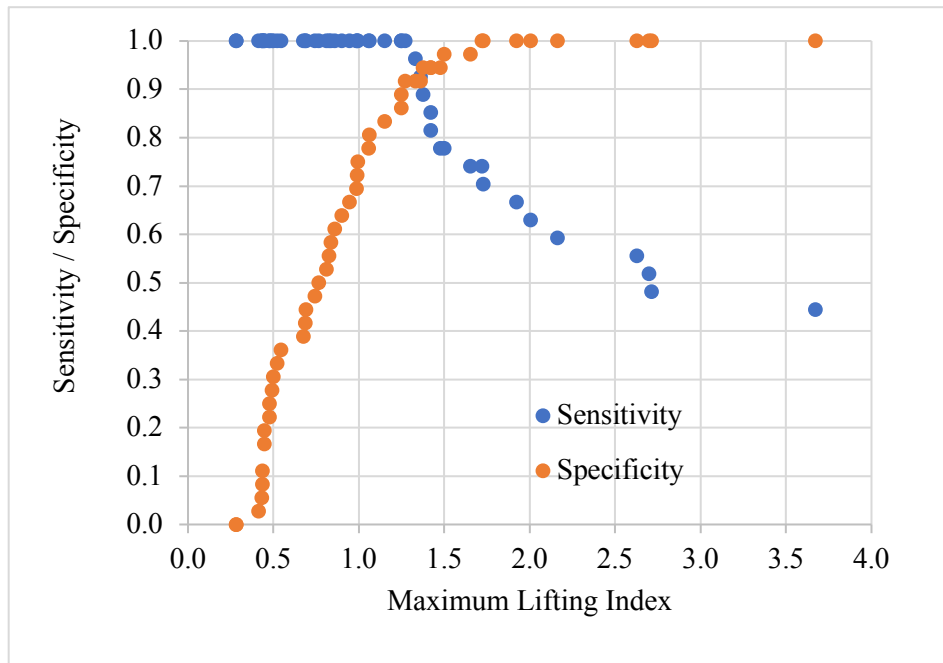


Figure 2. Sensitivity/Specificity vs. Maximum Lifting Index



## CHAPTER FIVE: DISCUSSION

Many of the risk factors listed in Table A1 (see appendix) are accounted for in the LI. For the LI to be a consistent metric to predict LBP in manufacturing setting, the accuracy of the metric predicting LBP must be high. Determining if the EST was able to accurately predict LBP is the purpose of this study.

MMH was helpful in finding cases of workers with LBP with a very high sensitivity of 0.96 and a specificity of 0.79. Standing was not associated with LBP. When standing is added to MMH, the sensitivity remains at 0.96 and the specificity remains at 0.79; again, indicating not predictive value. Shift length had very a weak sensitivity and specificity and does not appear to have an association with LBP.

The MaxLI alone was found to be statistically significant in predicting LBP. This metric is a good indicator for predicting LBP. The MaxLI is able to distinguish cases from non-cases. The higher the AUC is, the stronger the model is at predicting its outcome. This is shown with the ROC curve, it has an AUC of 0.98, which demonstrates the model's strong ability to predict LBP from MaxLI.

Referring to Figure 2, sensitivity and specificity plotted against MaxLI presents a cut point of 1.3 with a sensitivity of 0.96 and sensitivity of 0.89. This provides good results and when compared to other studies, it is slightly above a job task with a LI greater than or equal to 1.0 where there is a significant increase in LBP.

When examining Shift and MaxLI, MaxLI was again statistically significant but Shift was not. The effect likelihood ratio test that was done showed with statistical significance that there is an association between shift length and LBP.

## **CHAPTER 6: CONCLUSION**

This study assessed the use of the MaxLI to predict LBP. The EST uses this metric to achieve this goal. The LI incorporates many of the risk factors that are causes of LBP. The cut point for MaxLI of 1.3 can be used to determine that a task puts workers at an increased risk of developing LBP because of its good sensitivity at 0.96 and specificity at 0.89. The analysis in this study show that the MaxLI is a good predictor of LBP. Shift was also examined and there does not seem to be an association between shift length and LBP.

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## **APPENDICES**

## Appendix A: Table A1. Work characteristics considered by study

Table A1: Work characteristics considered by study.

Study	Weight	Frequency	Duration	Horizontal Location	Vertical Location	Travel Distance	Coupling	Combination Tasks	Asymmetry	Lifting Index	Composite Lifting Index	Peak Lifting Index	Peak Composite Lifting Index	Threshold Limit Value	Population Percentage	Other
Ciriello et al., 1990	✓	✓	✓					✓							✓	✓
Snook & Ciriello, 1991	✓	✓			✓	✓									✓	✓
Marras et al., 1999	✓	✓		✓	✓	✓			✓	✓						✓
Waters et al., 1999	✓	✓	✓	✓	✓	✓	✓		✓	✓						
Ciriello, 2003	✓	✓		✓											✓	✓
Ciriello, 2005	✓			✓		✓		✓							✓	✓
Waters et al., 2011	✓	✓	✓	✓	✓	✓	✓		✓	✓						
Pinder et al., 2011	✓	✓		✓	✓	✓	✓		✓	✓	✓					✓
Amick et al., 2011	✓	✓	✓	✓	✓									✓		
Garg, Boda, et al., 2014	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓
Garg, Kapellusch, et al., 2014	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓			✓
Kapellush et al., 2014	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓			✓
Lu et al., 2014	✓	✓	✓							✓	✓					



Table A1: Work characteristics considered by study (Continued)

Study	Outcome	Notes
Ciriello et al., 1990	The psychophysical method is suitable to determine maximum acceptable weights (MAW) for frequencies of 4.3 tasks per minute or slower. For a combination task, it was determined that the MAW is limited by the lowest acceptable weight of any of the factors.	This is based on the finding that there was no evidence of heart rate increase or excessive oxygen consumption where weights and forces in a 40-minute test were maintained for four hours
Snook & Ciriello, 1991	Represents best estimate of MAW and forces for industrial workers to help reduce disability from low back pain.	These tables can also help in the evaluation of workers in rehabilitation programs that preparing to return to work.
Marras et al., 1999	RNLE identifies high-risk jobs well unlike low-risk jobs.	Correctly identified 73% of the high-risk jobs.
Waters et al., 1999	LI appears to be to be a useful indicator for determining the risk of LBP caused by manual lifting.	A worker that performs a lifting job with a LI greater than two, has a significantly greater risk of having LBP lasting a week or more during a 12 month period than a worker performing a nonlifting job.
Ciriello, 2003	Existing guidelines show a conservative estimate for the various frequencies studied.	This study also quantified the effects of the 20 lifts/min lifting frequency.
Ciriello, 2005	Present guidelines show a conservative estimate of the variables that were studied except for the combination task for women.	MAWs of lowering were not significantly affected by vertical distance, height of lowering, or box size.
Waters et al., 2011	As LI increases, the risk of LBP increases.	Jobs with an LI greater than three, the odds ratio is nonsignificant.
Pinder et al., 2011	No significant evidence that LI or CLI is associated with LBP.	Strongest predictor of future LBP was a history of LBP.
Amick et al., 2011	While there are small differences between the measure of low back disorder (LBD) risk in the vertical and horizontal zones, the magnitude of the LBD risk as it relates to the TLV magnitude indicates that the TLV's represent low risk for the risk of LBD.	An assessment method for mono-lifting tasks based on horizontal and vertical locations of the object at the origin of the lift.
Garg, Boda, et al., 2014	PLI and PCLI are useful metrics for estimating exposure to job physical risk factors.	PLI and PCLI are defined as the highest LI and CLI from all subtasks and tasks performed by the worker.
Garg, Kapellusch, et al., 2014	PLI and PCLI are useful estimating risk of seeking care for LBP. PLI and PCLI are useful for estimating the risk of medication use for LBP from lifting.	Risk factors for seeking care for LBP are likely age, biomechanical stressors, history of LBP, and female gender.
Kapellusch et al., 2014	PLI and PCLI are useful for estimating the risk of medication use for LBP from lifting.	Sensitivity and specificity of the case definition for medication use for LBP could be affected by some cohort characteristics, such as the age, sex, LBP duration, history, patient preference, and physician recommendation for medication use.
Lu et al., 2014	CLI greater than two may be useful in estimating LBP.	The categorical mean and maximum CLI were greater than and two had a significant effect on self-reported LBP at one-year follow-up.

## Appendix B: Structured Interview Form

UAW-Ford Symptoms Interview  
Version 2.0

USF Job Code	
Job / Workstation Description	
Location	
Interviewer	
Date	

Was permission given to proceed with the interview?	YES -- Continue NO -- Stop
Have you worked at this workstation for more than a month?	YES -- Continue NO -- Stop
Have you had any muscle or joint pain or discomfort associated with this job in the past month?	YES -- Continue NO -- Stop

In what body region is/was the pain or discomfort most severe? Is/Was there pain or discomfort in other regions (if so, which ones)?	P—Primary O—Other
Neck or Shoulders	
Hands, Wrists or Elbows	
Low Back	
Other (specify):	

For the most severe pain or discomfort	Y—Yes N—No
Did the pain or discomfort interfere with your ability to do your job?	
Did the pain or discomfort interfere with your outside activities?	
Did the pain or discomfort interfere with your sleep?	
Did you seek treatment from the plant clinic?	
Did you seek treatment from a personal or private health care provider?	
Did you use non-prescription drugs, hot or cold compresses, or time off for recovery (sick leave or vacation)?	
Did you do anything else for relief? (Specify)	

For the other pain or discomfort	Y—Yes N—No
Did the pain or discomfort interfere with your ability to do your job?	
Did the pain or discomfort interfere with your outside activities?	
Did the pain or discomfort interfere with your sleep?	
Did you seek treatment from the plant clinic?	
Did you seek treatment from a personal or private health care provider?	
Did you use non-prescription drugs, hot or cold compresses, or take time off for recovery (sick leave or vacation)?	
Did you do anything else for relief? (Specify)	

## Appendix C: USF IRB Approval Letter



### NOT HUMAN SUBJECTS RESEARCH DETERMINATION

June 2, 2020

Colins Nwafor  
8655 Boardwalk Path Dr  
1522C  
Temple Terrace, FL 33637

Dear Mr. Colins Nwafor:

On 6/2/2020, the IRB reviewed the following protocol:

IRB ID:	STUDY001030
Title:	Assessment of the Effectiveness of UAW-Ford Ergonomic Assessment Tool (EST) for the Analysis of Low Back Musculoskeletal Disorders (LBMSDs)

The IRB determined that the proposed activity does not constitute research involving human subjects as defined by DHHS and FDA regulations.

IRB review and approval is not required. This determination applies only to the activities described in the IRB submission. If changes are made and there are questions about whether these activities constitute human subjects research, please submit a new application to the IRB for a determination.

While not requiring IRB approval and oversight, your project activities should be conducted in a manner that is consistent with the ethical principles of your profession. If this project is program evaluation or quality improvement, do not refer to the project as research and do not include the assigned IRB ID or IRB contact information in the consent document or any resulting publications or presentations.

Sincerely,

Jennifer Walker  
IRB Research Compliance Administrator

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**Institutional Review Boards / Research Integrity & Compliance**

FWA No. 00001669

University of South Florida / 3702 Spectrum Blvd., Suite 165 / Tampa, FL 33612 / 813-974-5638

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