

Analysis of Ergonomic Risk Levels in Manual Handling Activities Using the National Institute for Occupational Safety and Health (NIOSH) Lifting Equation Method with Upper Back Pain Complaints

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ABSTRACT

Background: Upper back pain (UBP) is stiffness in the back that starts from the area behind the neck to the waist, which can cause pain. One type of work that is at risk is loading and unloading work. Loading and unloading workers at the port manually carry out their work with loads that exceed the limits recommended by the National Institute for Occupational Safety and Health (NIOSH). Manual handling activities carried out continuously can risk causing complaints of pain in the upper back. This research aims to determine the recommended weight limit (RWL) and Lifting index (LI) values on loading and unloading workers, as well as to analyze the Ergonomic Risk Level in manual handling Activities using the NIOSH Lifting Equation method with UBPs complaints.

Methods: This research employs an analytic observational study with a cross-sectional design. The research sample employed an exhaustive sampling technique, involving as many as 50 participants. Measurement of ergonomic risk used questionnaires and the *NIOSH Lifting Equation*. Data analyzed using Spearman correlation test.

Results: Based on the calculation of Lifting Index (LI) value, most respondents work with a moderate risk level ($1 < 3$), namely 33 respondents (66%) and assesment result of UBPs complaints used a questionnaire showed that 19 respondents (38%) stated that they often experienced UBPs complaints due to their work activities, 14 respondents (28%) stated that they always felt UBPs complaints, and 3 respondents (6%) never experienced complaints. Spearman correlation test obtained $p\text{-value} = 0.000 (< 0.05)$ and $r = 0.727$.

Conclusion: There is a relationship between the risks of manual handling work and complaints of upper back pain in loading and unloading workers (TKBM). This relationship is strong and positive (unidirectional), meaning that the higher the risk of manual handling work, the higher the complaints of upper back pain experienced. If the manual handling risk value can be reduced, workers can avoid the risk of complaints of upper back pain.



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INTRODUCTION

Musculoskeletal Disorders (MSDs) are disorders or damage to the muscular and skeletal systems of the human body caused by an imbalance in the activity load against the ability of muscles and skeletons which significantly directly or indirectly reduces work productivity. If the muscles are subjected to repetitive static loads, it will affect the tendons, joints, muscles,

ligaments, and nerves. Skeletal muscle complaints generally occur due to excessive muscle contraction caused by heavy workloads with prolonged loading durations. Conversely, muscle complaints may not occur if muscle contraction is only around 15-20% of the maximum muscle strength. If muscle contraction exceeds 20%, blood circulation to the muscles will decrease, reducing oxygen supply to the muscles, inhibiting carbohydrate metabolism, and leading to lactic acid buildup, which causes muscle pain (Laksana & Srisantyorini, 2020). *Musculoskeletal disorders* had the second highest average prevalence, which is 34.54 cases per year. Based on the research conducted by Boas (2019) on The Relationship Between Ergonomic Risk Factors in Manual Handling Based on the NIOSH Lifting Equation Method and Subjective Complaints of Low Back Pain in the Construction of Bekasi Timur LRT Station, among the *musculoskeletal symptoms* experienced by Indonesian workers are muscle injuries in the lower neck (80%), shoulder (20%), back (40%), posterior lumbar (40%), back of the hip (20%), buttocks (20%), thigh (40%), knee (60%), and calf (80%) (Boas, 2019). One of the various types of *musculoskeletal complaints* (MSDs) includes *upper back pain* (Boas, 2019).

Research conducted by Triastuti (2020), on his research related to Factors Associated with Complaints of *Musculoskeletal Disorders* in Loading and Unloading Workers. Muscle Pain (*Musculoskeletal Disorders*) in Loading and Unloading Workers at Pantoloan Port Palu, it was found that there were 72 (92.3%) respondents who have complaints of muscle pain (*Musculoskeletal Disorders*) in the body parts complained of in the back, left hand and right hand after doing their work and right hand after doing their work (Triastuti et al., 2020).

The study conducted by Mayangsari (2020), titled Ergonomic Risk Analysis on Lifting Work in the Raw Material Warehouse of PT. XYZ Using the NIOSH Lifting Equation Method, found that the LI value was in the 1 - <3 category. This value indicates a high risk of spinal injuries. Modifying the load received by workers is one of the key factors in reducing the lifting risk index to less than one (Mayangsari et al., 2020). Another study related to ergonomic risk analysis using the NIOSH Lifting Equation method was conducted by Harini (2022) in the palm oil plantation industry. The study results showed that the workers' total CLI value was 2.85, indicating a moderate risk of musculoskeletal injuries (Harini, 2022).

Upper Back pain is defined as a feeling of stiffness and soreness that radiates up the spine from the base of the neck and thoracic spine to the waist and upper edge of the thoracic spine. Pain arises in the cervical spine region or radiates to the upper or lower back of the back. Back pain is a sign of stimulation of sensory nerve fibers in the back region caused by stimulation of muscles and bones. The term back describes the part of the spine that extends from the cervix to the tailbone (Hafifa, 2022). The thoracic region of the spine is the site of upper back pain, also known as upper back pain (UBP), it is estimated that 17.3 million people in the UK experience back pain (Boas, 2019). In Indonesia, the prevalence of *musculoskeletal disorders*, including upper back pain, is 24.7% based on self-diagnosis or symptoms and 11.9% based on diagnosis by medical personnel (Fernando, 2021).

Lifting is a common activity for industrial workers. It is a physically demanding job and can be quite dangerous if the working position and the load being lifted are not done with enough care. For workers, productivity and speed of execution are paramount. If not realized, workers who lift and lower objects may experience back problems, especially if the task is not done properly. Risks that exceed one's capacity can result in pain, discomfort, excessive stress, fatigue, accidents, injuries, and ineffective labor (Pratama & Ramlan, 2018).

One of the lifting and transporting jobs at risk of UBP usually occurs in workers at the port. Port is a facility located on the coast of the sea with the activity of receiving ships and transporting goods and passengers. The port is also the gateway to a certain area and becomes an infrastructure link between regions, between islands and even between countries (Hafifa, 2022). Loading and Unloading Workers (TKBM) play a crucial role in the lifting and transporting of goods. This job carries many risks, one of which is complaints of upper back pain (UBP). UBP complaints arise because TKBM lift and carry loads that exceed their capacity. The loads are mostly placed on the upper back, which can lead to injuries in that area.

UBP complaints can appeared due to factors of lifting and lowering the load lifted which is known as manual handling. Manual handling is one type of work that has a high risk of work

accidents (Agustin et al., 2020). *Manual Handling* is work that involves lowering, pushing, lifting, holding, pulling, carrying or moving heavy objects with one or both hands and/or controlling the whole body using muscle strength (Karani Maudy et al., 2021). Lifting objects that exceed the body's capacity without keeping the spine straight can put undue pressure on the upper back. Lifting or holding heavy objects above back can leave the shoulders and upper back vulnerable to injury (Seller, 2017).

In manual handling activities human power is still very much needed. When compared to using assistive devices, manual handling has advantages due to the flexibility of movements that can be performed for light loads. But besides that, manual handling activities can also cause occupational diseases and high risks. Manual handling activities can cause back pain caused by lifting 50%, pushing and pulling 9%, throwing, carrying, pulling and holding 6% (Khairani & Utami, 2021). Research conducted by Fabanjo, et al (2024) found that there is a relationship between Manual Handling and Low Back Pain Events in brick craftsmen workers (Fabanjo et al., 2024). Another study conducted by Rahayu (2022) found there was a relationship between manual handling risk and musculoskeletal complaints in construction workers as indicated by a p-value of $0.007 < 0.05$ and a value (r) of 0.49 which means that the strength of the relationship is quite strong and the direction of the relationship is positive (Rahayu, 2022).

Based on the results of research conducted by Suta, et al (2021) and statistical analysis with the Fisher exact test, it can be concluded that there is a relationship between the lifting index of porters and complaints of myogenic low back pain in the Denpasar traditional market. Samples with LI 'at risk' predominantly complained of myogenic LBP pain and samples with LI 'possibly at risk' predominantly did not complain of pain. The magnitude of the LI value is influenced by the transport load, work attitude and also the handle or basket used. The magnitude of the LI value is not influenced by age, latest education, duration of work and length of service (Suta et al., 2021).

NIOSH Lifting Equation is one of the methods used to assess ergonomic risks in manual handling tasks, alongside REBA, RULA, OWAS, the LMM Key Indicator, and other methods. However, some of these methods have limitations, such as only evaluating working posture without being able to calculate the recommended weight limit for a worker. The calculation of the recommended weight limit and the assessment of injury risk from a manual handling activity can be determined using the NIOSH Lifting Equation method. The *NIOSH Lifting Equation* method uses two Lifting Task Indicators to assess human work posture. The *Recommended Weight Limit* (RWL) method is a method that recommends the limit of the load lifted by humans without causing injury even though the work is done repetitively and for a long period of time. After calculating the RWL value, the Lifting Index (LI) value will be calculated. Lifting Index (LI) is used to determine the lifting index whether the lifting process poses a risk of spinal injury or not. When the Lifting Index exceeds 1 then the position can pose a risk of spinal injury. When the *Lifting Index* is less than 1 then the position does not pose a risk of spinal injury. *NIOSH Lifting Equation* method is expected to prevent workers from avoiding complaints of Upper Back Pain (Fahmi & Andesta, 2023).

Interviews with 8 loading and unloading workers (TKBM) at Gorontalo Branch, was found that the risk factor for manual handling work, obtained 7 (70.0%) with a lifting index (LI) value (1-<3) (medium) and 1 (10.0%) worker with a LI value ≥ 3 (high). This means that the weight of the load lifted has exceeded the lifting limit recommended by NIOSH and this type of work is at risk of injury. Beside that 7 loading and unloading workers (100%) at Gorontalo Branch experienced upper back pain complaints.

The novelty of this research lies in the research subject, namely the risk assessment of manual handling work carried out on loading and unloading workers (TKBM) who work at the port using the NIOSH method. In some previous studies, the risk assessment of manual handling work was carried out on other types of work. Based on this issue, the researcher is interested in conducting a study on the analysis of ergonomic risk levels in manual handling activities of loading and unloading workers using the NIOSH Lifting Equation method.

METHODS

This study used an analytical observational design with a cross-sectional study design. The population to be studied in this study is the loading and unloading workforce (TKBM) at PT Gorontalo Branch as many as 50 people. The research sampling technique used exhaustive sampling technique because By including the entire available population, the study can obtain more representative data and avoid sampling errors that may occur in random sampling methods. Data on upper back pain complaints were obtained through a questionnaire and an assessment of the ergonomic risk level of manual handling work using the *NIOSH Lifting Equation* Instrument.

Ergonomic Risk Assessment of Manual Handling Activities using the NIOSH Lifting Equation method. This instrument was developed by the National Institute for Occupational Safety and Health (NIOSH) and used to determined Recommended Weight Limit (RWL) and Lifting Index (LI). RWL is calculated by considering the distance from the palm of the hand to the midpoint between the two heels (Horizontal Location (H)), the distance between the two hands and the floor (Vertical Location (V)), the distance of the vertical height difference between the destination and the origin (Vertical Travel Distance (D)), the average number of lifts / minute (Lifting Frequency (F)), the angle of rotation when moving (Angle of Asymetric (A)), the classification of handrails (coupling classification (C)). (Lifting Index) is a simple estimation of the risk of injury caused by overexertion. Based on the weight of the load and the RWL value, the LI can be determined.

This research data was analyzed using the spearman correlation test. This research has obtained ethical approval from the Health Research Ethics Commission of Gorontalo State University with number: 125A/UN47.B7/KE/2024.

RESULTS

Respondent's Age

The age distribution of respondents was mostly in the age group of ≥ 35 years with 35 respondents (70%). while the other 15 respondents were in the age group of < 35 years (30%). Musculoskeletal problems begin to appear around the age of 35, and the level of complaints tends to increase with age. There is a higher likelihood of experiencing pain and muscle discomfort as muscle strength and endurance start to decline.

Recommended Weight Limit (RWL)

$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$

LC : (*Lifting Constanta*) = 23 kg

HM: (*Horizontal Multiplier*) = $25/H$

VM: (*Vertical Multiplier*) = $1-0,003[V - 75]$

DM: (*Distance Multiplier*) = $0,82 + 4,5/D$

AM: (*Asyementic Multiplier*) = $1-0,0032A(0)$

FM: (*Frequency Multiplier*)

CM: (*Coupling Multiplier*)

Table 1. The distribution of Recommended Weight Limit (RWL) value

No	LC	HM	VM	DM	AM	FM	CM	RWL
1	23	1.7857143	1	0.9	1	1	0.95	33.873353
2	23	0.8928571	1	0.91	1	1	0.95	17.486828
3	23	1.7857143	1	0.92	1	1	0.95	35.013508
4	23	1.5625	1	0.93	1	1	0.95	31.358591
5	23	1.3888889	1	0.92	1	1	0.95	26.663069
6	23	1.3888889	1	0.97	1	1	0.95	28.995253
7	23	1.9230769	1	0.93	1	1	0.95	36.244213
8	23	1.3888889	1	0.93	1	1	0.95	25.013091
9	23	1.3888889	1	0.97	1	1	0.95	26.345941
10	23	1.1904762	1	0.92	1	0.94	0.95	22.483014
11	23	1.3888889	1	1.02	1	0.88	0.95	27.114806

No	LC	HM	VM	DM	AM	FM	CM	RWL
12	23	1.3157895	1	0.97	1	0.84	0.95	22.959015
13	23	1.25	1	0.9	1	0.84	0.95	19.609528
14	23	1.3888889	1	0.93	1	0.88	0.95	24.529387
15	23	1.4705882	1	1	1	0.91	0.95	28.801835
16	23	1	1	1.27	1	0.8	0.95	21.200618
17	23	1.25	1	1.72	1	0.8	0.95	35.32708
18	23	1.25	1	1.05	1	0.8	0.95	21.805754
19	23	1.6666667	1	1.72	1	0.8	0.95	45.599493
20	23	1.3888889	1	1.27	1	0.8	0.95	29.445303
21	23	1.3888889	1	1.27	1	0.84	0.95	31.8888
22	23	1.25	1	1.27	1	0.84	0.95	26.951702
23	23	1.25	1	1.27	1	0.84	0.95	27.388757
24	23	1.4705882	1	1	1	0.91	0.95	28.801835
25	23	1	1	1.27	1	0.8	0.95	21.200618
26	23	1.25	1	1.72	1	0.8	0.95	35.32708
27	23	1.25	1	1.05	1	0.8	0.95	21.805754
28	23	1.6666667	1	1.72	1	0.8	0.95	45.599493
29	23	1.3888889	1	1.27	1	0.8	0.95	29.445303
30	23	1.3888889	1	1.27	1	0.84	0.95	31.8888
31	23	1.25	1	1.27	1	0.84	0.95	26.951702
32	23	1.25	1	1.27	1	0.84	0.95	27.388757
33	23	1.4705882	1	1	1	0.84	0.95	26.586309
34	23	1	1	1.27	1	0.91	0.95	24.115703
35	23	1.25	1	1.72	1	0.8	0.95	35.32708
36	23	1.25	1	1.05	1	0.8	0.95	21.805754
37	23	1.6666667	1	1.72	1	0.8	0.95	45.599493
38	23	1.3888889	1	1.27	1	0.8	0.95	29.445303
39	23	1.3888889	1	1.27	1	0.8	0.95	30.370286
40	23	1.25	1	1.27	1	0.84	0.95	26.951702
41	23	1.25	1	1.27	1	0.84	0.95	27.388757
42	23	1.4705882	1	1	1	0.84	0.95	26.586309
43	23	1	1	1.27	1	0.91	0.95	24.115703
44	23	1.25	1	1.72	1	0.8	0.95	35.32708
45	23	1.25	1	1.05	1	0.8	0.95	21.805754
46	23	1.6666667	1	1.72	1	0.8	0.95	45.599493
47	23	1.3888889	1	1.27	1	0.8	0.95	29.445303
48	23	1.3888889	1	1.27	1	0.8	0.95	30.370286
49	23	1.25	1	1.27	1	0.84	0.95	26.951702
50	23	1.25	1	1.27	1	0.84	0.95	27.388757

Based on the calculation of the Recommended Weight Limit (RWL), it was found that 32 respondents (64%) lifted loads exceeding the recommended limit. The types of loads lifted varied, including passenger luggage, motor vehicles, fertilizers, cement, and harvested crops. The weight of the lifted loads also varied, with the maximum weight lifted by workers reaching 50 kg. The grip or coupling condition of the objects was generally classified as fair.

Lifting Index (LI)

Table 2. The distribution of *Lifting Index* value

<i>Lifting Index</i> (LI)	Risk Level	n (50)	%
< 1	Low	17	34.0
1 - < 3	Moderate	33	66.0

Based on the calculation of the LI value, the majority of respondents, namely 33 respondents (66%), fell into the medium-risk category with an LI value of 1 - < 3, while 17 respondents (34%) were in the low-risk category with an LI value of < 1.

Upper Back Pain Complaints

The assessment results of upper back pain complaints showed that 19 respondents (38%) stated that they often experienced complaints due to their work activities. 14 respondents (28%) reported experiencing upper back pain, while the remaining 3 respondents (6%) stated that they had never experienced upper back pain complaints.

Tabel 3. Distribution of respondents based on complaints of *upper back pain* at PT Pelindo (Persero) Regional IV Gorontalo Branch.

Complaints of <i>Upper Back Pain</i>	n (50)	%
Always	14	28.0
Often	19	38.0
Sometimes	5	10.0
Rarely	9	18.0
Never	3	6.0

The relationship between the risk of *manual handling* work with complaints of *upper back pain* at Gorontalo Branch

Table. 4 The relationship between the risk of *manual handling* work with complaints of *upper back pain* at Gorontalo Branch

LI	<i>Upper Back Pain Complaints</i>										Total		<i>p-value</i>	r
	Never		Rarely		Sometimes		Often		Always					
	n	%	n	%	n	%	n	%	n	%	n	%		
< 1	3	17.6	9	52.9	5	29.4	0	0.0	0	0.0	17	100	0.00	0.727
1-<3	0	0.0	0	0.0	0	0.0	19	57.6	14	42.4	33	100		

Based on bivariate analysis, it was found that 33 respondents (66%) work with a moderate risk level, 19 respondents (57.6%) of them often experience complaints of *upper back pain* and 14 respondents (42.4%) always experience complaints of *upper back pain*. Meanwhile, of the 17 respondents (34%) working with a low level of risk, 5 respondents (29.4%) experienced complaints of upper back pain with occasional frequency, 9 respondents (52.9%) experienced complaints of *upper back pain* with rare frequency, and 3 respondents (17.6%) never experienced complaints of *upper back pain*.

Spearman correlation statistical test showed that $p\text{-value} = 0.000$ and $r = 0.727$, indicating that there is a relationship between the risk of manual handling work and complaints of upper back pain among loading and unloading workers (TKBM) at Gorontalo Branch. This relationship is strong and positive (unidirectional), meaning that the higher the risk of manual handling work, the more likely you will experience upper back pain.

DISCUSSION

Manual handling activities which include pushing, lowering, lifting, pulling and carrying are the main causes of employee complaints in industry. The increase in the level of injuries or accidents can cause pain or complaints in workers which leads to a decrease in the productivity of workers and companies, besides that it also has a personal impact on workers related to disorders of the human *muscular skeletal system*. In addition to physical losses, it also causes losses through the burden of high medical costs and also worker absenteeism and a decrease in the quality of work. Most workers in doing their work, their work posture is not *ergonomic* or not in accordance with the principles of ergonomics, namely the spine is too bent, the reach exceeds the length of the worker's hand reach, and loads that exceed recommended limits (Sanjaya et al., 2018).

The results showed there is a relationship between the risk of *manual handling* work with complaints of *upper back pain* in TKBM at Gorontalo Branch, and the strength of the relationship between the two variables is strong, with a positive relationship direction (unidirectional), which means that the higher the level of risk of manual handling work, the greater the risk of upper back

pain complaints. The high intensity and type of manual handling work can contribute to an increase in the frequency and severity of health complaints experienced by the workers. If the manual handling risk value can be reduced, workers can avoid the risk of complaints of upper back pain. This is because based on the RWL dan LI calculation in *NIOSH Lifting Equation* that the load lifted by TKBM has exceeded the recommended ability limit and most of respondents are in the medium-risk job category so that workers experience upper back pain complaints.

Work that is done repeatedly, using poor work postures/attitudes and *manual handling* processes will cause back pain complaints. One of the factors contributing to the prevalence of *low back pain* is a person's attitude towards work. *Back pain* can be caused by improper body alignment or attitudes that force themselves beyond their abilities (Masloman et al., 2018). Working positions in lifting or lowering objects are *manual handling* activities. Poor *manual handling* practices can result in injury or even death to workers. In addition, manual handling is the most significant and frequent factor resulting in injuries to all workers worldwide (Nuraini, 2012). This is due to the excessive use of muscles and body tissues that are not in accordance with the body's capacity, which will eventually reduce the function of these muscles and tissues (Wahyudin et al., 2025).

Based on the findings of the study by Wahyudi et al (2025), it was found that there is a significant relationship between manual handling activities and musculoskeletal disorders (MSDs) complaints among stone miners, with a p-value of 0.001, which is smaller than the alpha value of 0.05. This indicates that the heavier and riskier the manual handling activities performed, the greater the likelihood of workers experiencing musculoskeletal disorder complaints. In other words, the high intensity and type of manual handling work can contribute to an increase in the frequency and severity of health complaints experienced by the miners.

For laborers, productivity and work speed are the most crucial factors. Unbeknownst to you, the activity of workers raising and lowering an object could have resulted in a spinal cord injury, especially if the work is not done properly. An event will occur if the hazard is higher than the individual's capacity and can ultimately be caused by pain, discomfort, excessive stress, fatigue, accidents, injuries, and ineffective labor (Pratama & Ramlan, 2018).

This study is in line with research by Boas, (2019) that the p value = 0.002 < 0.05 indicates a substantial correlation between back pain complaints and *ergonomic* risks determined by the *NIOSH lifting equation* approach. According to the *NIOSH lifting equation*, 36 (85.7%) employees exposed to ergonomic hazards reported back pain. Another study by Setyowati et al (2017) p-value = 0.018 < α = 0.05 at the Merak-Banten Ferry Port port, showed a relationship between the risk of transporting goods and complaints of neck discomfort (Boas, 2019). This study is also in line with the research conducted by Kharisma (2021), There is a significant relationship between the risk of manual handling work and musculoskeletal complaints among female porters at Pasar Legi Surakarta, with a p-value of 0.040 < 0.05 and an r-value of 0.233, which falls into the low category and indicates a positive correlation (Kharisma, 2021). Another study conducted by Aulia (2023) on office workers at PT X and analyzed using the chi square test obtained a p-value of 0.001 < 0.05, which means that H_0 is rejected, which means that there is a significant relationship between work posture and musculoskeletal complaints in office employees at PT X (Aulia et al., 2023).

The limitation of this study is that the researcher did not examine other factors that contribute to the occurrence of upper back pain complaints, such as individual factors (smoking habits, medical history, work stress, physical activity, work posture) and workplace environmental factors such as vibration.

CONCLUSION

Based on the result of the *spearman correlation* test there is a significant relationship between the risk of *manual handling* work and complaints of *upper back pain* in loading and unloading workers (TKBM) at Gorontalo Branch. The recommendations that can be given include using transport aids such as trolleys when carrying out lifting and carrying activities to reduce muscle complaints and avoiding awkward postures, such as carrying items with unbalanced loads,

to prevent muscle discomfort. Beside that for future research recommended to study other factors that may influence upper back pain complaints.

Author's Contribution Statement: Putri Ayuningtias Mahdang: Research ideas and concepts, supervision of research proposal drafting, administration, processing research results, and scientific article drafting. Tri Septian Maksum: computing, supervision, visualization, data processing methodology, and reviewing research articles for scientific publication.

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