Integrated Cardiovascular and Ergonomic Assessment in Rice Warehousing Activities

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ABSTRACT

Physical workload is a critical factor affecting worker safety, fatigue, and operational efficiency in manual material handling activities. This study develops an integrated evaluation approach combining Cardiovascular Load (CVL) and ergonomic assessment to analyze physical workload in manual rice warehousing operations. Data were collected through heart rate measurements using an oximeter, worker characteristics, working duration, and direct ergonomic observations of manual handling activities. The CVL method was applied to quantify physiological workload, while ergonomic risk factors were assessed based on work posture, repetitive movements, and manual lifting activities. The results show that workers experience moderate physical workload levels with %CVL values ranging from 29% to 32%. Ergonomic assessment indicates that repetitive lifting, bending postures, and continuous carrying activities contribute to increased fatigue risk. The integration of physiological and ergonomic indicators provides a more comprehensive evaluation compared to single-method approaches. The proposed model highlights the importance of combining biomechanical and physiological factors in workload assessment. The study recommends ergonomic intervention strategies, workload redistribution, and improvement of manual handling procedures to reduce fatigue and enhance worker safety and productivity.

Introduction

Physical workload is a major determinant of worker health, fatigue, and productivity in manual material handling environments. In warehouse operations, workers are frequently exposed to repetitive lifting, carrying, pushing, and bending activities that impose significant physiological stress. Prolonged exposure to such activities may increase cardiovascular strain and musculoskeletal disorder risks, particularly when ergonomic principles are not adequately applied [1], [2].

Manual rice warehousing operations involve continuous handling of heavy loads, typically performed without mechanical assistance. These activities require repetitive physical effort, including lifting rice sacks, transporting loads over distances, and maintaining awkward postures during handling tasks. Such working conditions contribute to increased physical and physiological workload among workers.

Previous studies have widely used the Cardiovascular Load (CVL) method to assess physiological workload based on heart rate responses during work activities [3], [4]. CVL provides an objective measure of physical strain; however, it does not fully capture biomechanical and ergonomic risk factors such as posture deviation, repetitive motion, and manual handling techniques.

Ergonomic assessment methods emphasize the importance of posture, movement repetition, and load handling techniques in determining occupational risk levels [5], [6]. Poor ergonomic conditions combined with highphysiological demand may accelerate fatigue development and reduce work efficiency.

Therefore, an integrated approach combining physiological workload measurement and ergonomic assessment is required to obtain a more comprehensive understanding of worker burden. This study aims to develop an integrated physical workload evaluation model based on Cardiovascular Load and ergonomic risk factors in manual rice warehousing operations. The proposed model is expected to support better decision-making in workplace design, workload management, and occupational health improvement.

Methods

This study was conducted in a manual rice warehousing operational environment in Makassar, Indonesia. A quantitative descriptive approach was used to evaluate physical workload based on physiological and ergonomic indicators.

Data were collected through direct observation, heart rate measurements, and ergonomic assessment during manual material handling activities. Heart rate data were recorded using a digital oximeter during working and resting conditions. Worker characteristics such as age and working duration were also recorded.

The study population consisted of four warehouse workers performing manual loading and unloading tasks. A saturated sampling technique was applied, involving all available workers as research subjects.

Variables in this study include:

1. Physiological workload: resting heart rate, working heart rate, maximum heart rate, and Cardiovascular Load (%CVL).
2. Ergonomic risk factors: work posture, repetitive motion, and manual lifting activities.
3. Worker characteristics: age and working time.

The Cardiovascular Load (%CVL) method was used to determine workers' physiological workload levels. The maximum pulse rate was calculated using the following equation:

$HRmax = 220 - Age$ (1)

Where:
$HRmax$= maximum heart rate Age = worker age (years)

The percentage of HR Reserve was calculated using the following equation:

$$\%HR\ Reserve = \frac{HRwork - HRRest}{HR\text{max} - HRRest} \times 100\% \quad (2)$$

Where:
HRwork = working pulse rate
HRrest = resting pulse rate
HRmax = maximum pulse rate

The Cardiovascular Load (%CVL) value was calculated using the following equation:

$$\%CVL = 100 \times \frac{HRwork - HRRest}{HR\text{max} - HRRest} \quad (3)$$

Where:
HRwork = working pulse rate
HRrest = resting pulse rate
HRmax = maximum pulse rate
Energy consumption was calculated using the following equation:

$Y = 1.80411 - 4.71711 \times 10 - 4X2$ (4)
Where:
Y = energy consumption (kcal/minute) X = heart rate (beats/minute)

The research flow began with field observation and worker identification, followed by pulse rate measurements, ergonomic observations, data processing using the CVL method, energy consumption calculations, workload classification, and development of integrated workload evaluation recommendations.

Results and Discussions

The results indicate that manual rice loading and unloading activities in a warehouse environment involve continuous repetitive material handling tasks with high physical demands. Workers are required to manually transport rice sacks from trucks to storage areas and vice versa using shoulder carrying and lifting techniques, which require sustained muscular effort and energy expenditure.

During field observations, workers frequently adopted non-neutral body postures such as forward bending, asymmetric load carrying, and repetitive lifting movements. In addition, repetitive walking and prolonged manual handling activities were consistently observed throughout operational hours. These working conditions indicate the presence of ergonomic risk factors that may contribute to fatigue accumulation and musculoskeletal disorder risks.

Table 1. Heart Rate Data of Warehouse Workers

Name	Age	Working pulse rate	Resting pulse rate	Maximum pulse rate
Lia	55	99	69	165
Basri	49	99	68	171
Jama	50	98	67	170
Jumi	49	99	68	171

Based on heart rate measurements obtained during working periods, the workers exhibited moderate physiological workload levels according to the Cardiovascular Load (%CVL) classification. The calculated %CVL values ranged between 29% and 32%, indicating that while the workload is not categorized as hazardous, it requires ergonomic and operational improvements to prevent long-term fatigue accumulation.

Table 2. Cardiovascular Load (%CVL) Results

Name	%CVL Work Period I	%CVL Work Period II	Workload Classification
Lia	31,25%	31,63%	Improvement required
Basri	30,09%	29,41%	Moderate workload
Jama	30,09%	30,39%	Improvement required
Jumi	30,09%	29,80%	Moderate workload

The results further indicate that workers engaged in frequent lifting and repetitive manual handling tasks tend to exhibit higher cardiovascular responses. This suggests that ergonomic factors such as posture, load distribution, and movement repetition significantly influence physiological workload levels during warehouse operations.

Energy expenditure analysis also shows that workers require moderate energy consumption during operational activities, ranging from 241 kcal/hour to 249 kcal/hour. These values are consistent with moderate workload classification, indicating sustained physical effort throughout working periods.

Table 3. Energy Consumption Results

Worker	Energy Consumption (kcal/hour)
Lia	245–249
Basri	241–249
Jama	241–249
Jumi	241–249

The integration of Cardiovascular Load analysis and ergonomic observation provides a more comprehensive evaluation compared to physiological measurement alone. While CVL reflects internal physiological strain, ergonomic assessment captures external workload factors such as posture deviation, repetitive motion, and manual handling behavior.

This combined approach demonstrates that moderate CVL values may still present occupational risk when accompanied by poor ergonomic conditions. Therefore, workload assessment should not rely solely on physiological indicators but must incorporate ergonomic risk evaluation to obtain a more accurate representation of worker burden.

From a practical perspective, ergonomic improvements are required to reduce physical strain and improve operational efficiency. Recommended interventions include reducing repetitive lifting frequency, improving manual handling techniques, optimizing work–rest scheduling, and ensuring adequate recovery strategies such as hydration and nutritional support.

Conclusions

This study develops an integrated physical workload evaluation model based on Cardiovascular Load and ergonomic assessment in manual rice warehousing operations. The findings indicate that workers experience moderate physiological workload levels, accompanied by significant ergonomic risk factors related to posture and repetitive manual handling activities.

The integration of physiological and ergonomic approaches provides a more comprehensive framework for assessing occupational workload compared to single-method evaluation. The results highlight the importance of ergonomic intervention and workload management in reducing worker fatigue and improving operational efficiency.

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Author Contributions

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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