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Control Room Operator Ergonomic Risk Analysis Using the Nordic Body Map (NBM) and Rapid Office Strain Assessment (ROSA) in the Energy Department

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Abstract
Control room operators face working conditions characterized by prolonged sitting postures, high visual workload, and significant time pressure while monitoring systems. Inappropriate chair design that does not meet anthropometric requirements, monitor positions that are too high or too low, and keyboards or mice placed too far from the operator can lead to physical discomfort. This study aims to analyze ergonomic risks among control room operators based on working postures and musculoskeletal complaints experienced during work activities.The research was conducted using an observational method with an ergonomic approach. Data were collected through interviews, completion of the Nordic Body Map (NBM) questionnaire, and direct observation of operators' working postures, which were subsequently assessed using the Rapid Office Strain Assessment (ROSA) method. Operators' physical characteristics, such as body height and body proportions, were obtained based on self-reported statements and used as supporting data in the analysis. The results based on the NBM questionnaire showed that 5 out of 6 operators were classified as having a low risk, while 1 operator was classified as having a moderate risk. However, the working posture assessment using the ROSA method indicated that all operators obtained scores greater than 5, suggesting that the working conditions are at an ergonomic risk level that requires corrective action. Further analysis revealed that the work chair was the workstation component contributing most significantly to the high ROSA scores, particularly in relation to seat height adjustment, backrest configuration, and body support during work activities. Based on these findings, improvements to work facilities are necessary, with priority given to adjusting work chairs in accordance with ergonomic principles. Such improvements are expected to reduce ergonomic risks, prevent musculoskeletal disorders, and enhance operator comfort and work productivity.

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1. Introduction

The rapid development of industry in the era of the Fourth Industrial Revolution has intensified the integration of automation technology, digital control systems, and human–machine interaction. In such complex systems, human operators remain a critical component, particularly in control rooms where real-time monitoring and decision-making are required. Ergonomics plays a vital role in aligning work systems with human capabilities and limitations in order to improve productivity, safety, and overall system performance. Non-ergonomic working conditions may lead to fatigue, decreased performance, and musculoskeletal disorders (MSDs), which can ultimately affect both workers' well-being and organizational efficiency.

The steel industry represents a high-intensity working environment due to continuous production processes and complex energy systems that support operations. At PT Dexin Steel Indonesia, the Energy Department is responsible for ensuring the availability and stability of essential energy resources such as water, electricity, and steam. Control room operators are required to monitor these systems continuously through computer-based interfaces. As a result, control rooms are characterized by high static ergonomic exposure, where operators spend long periods in seated postures, maintain sustained visual focus on monitors, and perform minimal physical movement. Over extended durations, such conditions may lead to muscle tension and discomfort in the lower back, shoulders, and neck, particularly when workstation design does not conform to ergonomic principles.

Previous studies have reported that prolonged sitting, inappropriate chair design, improper monitor height, and poorly positioned input devices can significantly increase the risk of musculoskeletal complaints among computer-based workers. For example, Suryani *et al*. reported that a substantial proportion of office workers experienced MSD symptoms in the neck, back, and shoulders due to non-ergonomic working postures. Additional factors such as long work shifts, limited active rest periods, and suboptimal environmental conditions further exacerbate these risks. In the context of control room operations, these risk factors are often amplified by extended shift schedules and high cognitive demands. Ergonomic improvement is closely related to the effectiveness of work systems and productivity enhancement in industrial environments. Previous studies have emphasized that systematic evaluation of work processes and performance indicators plays an important role in supporting human performance and operational efficiency (Padhil *et al*., 2022) [7]. Padhil *et al*. (2024) [8] highlighted that structured performance measurement frameworks in industrial settings contribute to identifying improvement opportunities within work systems, which aligns with the role of ergonomics in optimizing human–machine interaction and reducing work-related risks.

Although ergonomic studies focusing on office workers are widely available, research specifically addressing control room operators in the steel industry remains limited. Control room operators differ from typical office workers in terms of task characteristics, exposure duration, interaction with control panels and alarm systems, and shift-based work patterns. These differences may contribute to unique ergonomic risk profiles that require targeted assessment. Furthermore, ergonomic risk assessment is mandated by occupational safety and health regulations in Indonesia, including Law No. 1 of 1970 on Occupational Safety and Government Regulation No. 50 of 2012 on the Occupational Safety and Health Management System, which require companies to identify hazards and assess workplace risks. Minister of Manpower Regulation No. 5 of 2018 explicitly identifies ergonomics as a workplace hazard factor that must be controlled.

Therefore, this study aims to analyze ergonomic risks among control room operators in the Energy Department of PT Dexin Steel Indonesia using the Nordic Body Map and Rapid Office Strain Assessment methods. By combining subjective musculoskeletal complaints with objective workstation and posture assessment, this research is expected to provide a comprehensive overview of ergonomic conditions in the control room and serve as a basis for practical ergonomic improvements in industrial control room environments.

2. Literature Review

2.1. Ergonomics and Musculoskeletal Disorders

Ergonomics is a scientific discipline concerned with understanding interactions between humans and other elements of a system, and applying this knowledge to optimize human well-being and overall system performance. In industrial settings, poor ergonomic design is widely recognized as a major contributing factor to musculoskeletal disorders (MSDs), particularly in tasks involving prolonged static postures, repetitive movements, and inadequate workstation design. MSDs commonly affect the neck, shoulders, lower back, and upper limbs, and may result in reduced work capacity, increased absenteeism, and decreased productivity. Several studies have demonstrated that prolonged sitting and static working postures significantly increase biomechanical load on the musculoskeletal system. Inadequate chair design, improper seat height, insufficient lumbar support, and limited adjustability can lead to excessive spinal loading and muscle fatigue. Over time, these conditions may cause chronic discomfort and increase the risk of developing work-related MSDs. Therefore, ergonomic intervention focusing on workstation design is essential, particularly in computer-based work environments.

2.2. Ergonomics in Control Room Environments

Control rooms represent a unique work environment characterized by continuous monitoring tasks, high cognitive demand, and minimal physical movement. Operators are required to maintain sustained attention to visual displays while responding promptly to alarms and system changes. As a result, control room work is associated with high static ergonomic exposure, especially during long shifts.

In industrial sectors such as steel manufacturing, control room operators are exposed to additional risk factors, including extended working hours, shift work, and time pressure. Studies have reported that control room operators frequently experience discomfort in the neck, shoulders, and lower back due to prolonged sitting and non-neutral postures. Compared to conventional office workers, control room operators often interact with multiple screens and control panels, which may further increase ergonomic risk when workstation layout is not properly designed.

2.3. Nordic Body Map as a Tool for Assessing Musculoskeletal Complaints

The Nordic Body Map (NBM) is a widely used questionnaire designed to identify subjective musculoskeletal complaints across different body regions. The method allows workers to report the presence and severity of discomfort experienced during or after work activities. NBM is particularly useful for early detection of MSD symptoms, as it captures workers' perceived discomfort before clinical conditions develop.

In ergonomic studies, NBM is often applied to evaluate the prevalence and distribution of musculoskeletal complaints among workers exposed to static postures or repetitive tasks. Although NBM does not directly assess workstation design, it provides valuable insight into how workers experience physical strain. Previous research has shown that low NBM risk categories do not necessarily indicate safe ergonomic conditions, especially when exposure duration is long and preventive measures are absent.

2.4. Rapid Office Strain Assessment for Workstation Evaluation

Rapid Office Strain Assessment (ROSA) is an observational method developed to evaluate ergonomic risk associated with office workstations, particularly those involving computer use. ROSA assesses key workstation components, including chair design, monitor position, keyboard and mouse placement, and telephone use. Each component is scored based on posture and adjustability, resulting in a final risk score.

A ROSA final score greater than 5 indicates a high ergonomic risk level and suggests that corrective action is required. ROSA has been widely applied in office and control room settings due to its practicality and ability to identify specific workstation elements that contribute most significantly to ergonomic risk. In several studies, high ROSA scores were strongly associated with poor chair design and improper monitor height, emphasizing the importance of adjustable seating and display configuration.

3. Methodology

3.1. Research Design

This study employed an observational cross-sectional research design using an ergonomic assessment approach. The objective of the study was to identify ergonomic risks associated with working posture and workstation configuration among control room operators during routine monitoring activities. The assessment was conducted at a single point in time without any intervention, focusing on both subjective musculoskeletal complaints and objective ergonomic risk factors.

3.2. Study Location and Subjects

The study was conducted in the control room of the Energy Department at PT Dexin Steel Indonesia, a steel manufacturing company with continuous production operations. The research subjects consisted of six active control room operators who routinely performed monitoring tasks using computer-based systems.

A total sampling technique was applied, in which all operators assigned to the control room were included as research subjects. This approach was used due to the limited number of operators and to ensure comprehensive representation of ergonomic conditions in the control room.

3.3. Work Description

Control room operators were responsible for continuously monitoring energy system parameters through multiple computer screens during working shifts. The tasks required operators to remain seated for prolonged periods, maintain sustained visual focus on monitors, and perform minimal physical movement. These working conditions resulted in high static postural exposure, particularly affecting the neck, shoulders, back, and upper limbs.

3.4. Data Collection Procedures

Data collection was carried out using a combination of interviews, questionnaires, and direct observation:

1. Interviews

Semi-structured interviews were conducted to obtain information related to work duration, shift patterns, perceived discomfort during work, and general workstation conditions.

2. Nordic Body Map (NBM) Questionnaire

Subjective musculoskeletal complaints were assessed using the Nordic Body Map (NBM) questionnaire. Operators were asked to indicate the presence and level of discomfort experienced in specific body regions during or after work. The NBM results were then categorized into ergonomic risk levels (low, moderate, or high) based on the total score obtained. The NBM form used in this study is presented in Figure 1. The questionnaire consists of a body map divided into specific regions, allowing operators to indicate the presence and intensity of discomfort experienced during or after work activities.

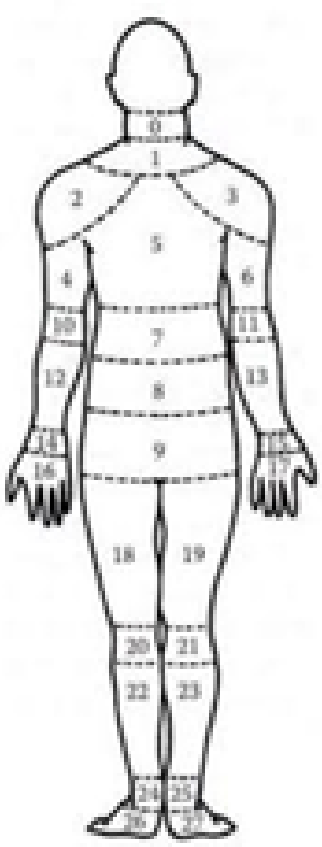
Kuesioner Nordic Body Map (NBM)

Nama Responden :

Umur :

Lama Bekerja :

Berikanlah tanda centang (√) pada kolom yang tersedia sesuai dengan apa yang Anda rasakan pada bagian sesuai pada gambar.



No.	Jenis Keluhan	Tingkat Keluhan			
		1	2	3	4
0	Sakit/kaku pada leher bagian atas				
1	Sakit/kaku pada leher bagian bawah				
2	Sakit pada bahu kiri				
3	Sakit pada bahu kanan				
4	Sakit pada lengan atas kiri				
5	Sakit pada punggung				
6	Sakit pada lengan atas kanan				
7	Sakit pada pinggang				
8	Sakit pada bokong				
9	Sakit pada pantat				
10	Sakit pada siku kiri				
11	Sakit pada siku kanan				
12	Sakit pada lengan bawah kiri				
13	Sakit pada lengan bawah kanan				
14	Sakit pada pergelangan tangan kiri				
15	Sakit pada pergelangan tangan kanan				
16	Sakit pada tangan kiri				
17	Sakit pada tangan kanan				
18	Sakit pada paha kiri				
19	Sakit pada paha kanan				
20	Sakit pada lutut kiri				
21	Sakit pada lutut kanan				
22	Sakit pada betis kiri				
23	Sakit pada betis kanan				
24	Sakit pada pergelangan kaki kiri				
25	Sakit pada pergelangan kaki kanan				
26	Sakit pada kaki kiri				
27	Sakit pada kaki kanan				

Keterangan:

1 = Tidak sakit

2 = Sedikit sakit

3 = Sakit

4 = Sangat sakit

Fig 1: Nordic Body Map questionnaire used for assessing musculoskeletal complaints among control room operators

3. Direct Observation of Working Posture

Direct observations were conducted to evaluate operators' sitting posture and workstation configuration during normal monitoring activities. Observations focused on body posture, chair usage, monitor position, keyboard and mouse placement, and interaction with workstation components. The working posture and workstation configuration of control room operators were documented through direct observation during routine monitoring activities. Figure 1 illustrates the typical sitting posture of operators while interacting with computer-based control systems.

Fig 1: Sitting posture of control room operators during routine monitoring activities

3.5. Ergonomic Risk Assessment Using ROSA

Objective ergonomic risk assessment was performed using the Rapid Office Strain Assessment (ROSA) method. ROSA evaluates ergonomic risk based on workstation design and operator posture during computer-based work.

The assessment included the following workstation components:

1. Work chair (seat height, seat depth, backrest, and armrests)
2. Monitor position (height and viewing distance)
3. Keyboard and mouse placement
4. Telephone usage (if applicable)

Each component was scored according to the ROSA assessment guidelines. Individual component scores were then combined to obtain a final ROSA score for each operator. A final ROSA score greater than 5 indicates a high level of ergonomic risk and the need for corrective action.

3.6. Supporting Operator Characteristics

Operators' physical characteristics, including body height and body proportion, were obtained based on self-reported data from each operator. These characteristics were used as supporting information in the analysis to help interpret the suitability of workstation dimensions relative to operator anthropometry.

3.7. Data Analysis

The collected data were analyzed descriptively. NBM results were used to describe the distribution of musculoskeletal complaints among operators, while ROSA scores were used to identify ergonomic risk levels and the workstation components contributing most significantly to these risks. The results of both methods were then compared to identify discrepancies between subjective complaints and objective ergonomic risk conditions.

4. Results

4.1. Operator Characteristics

The study involved six control room operators working in the Energy Department of PT Dexin Steel Indonesia. The operators exhibited variations in physical characteristics, particularly body height and body proportion. However, all operators performed similar job tasks and utilized comparable workstation configurations.

Despite differences in anthropometric characteristics, the workstations used by the operators were largely uniform and had limited adjustability, especially in terms of chair height and backrest configuration. Anthropometric data obtained through self-reported information were used as supporting data to interpret posture suitability during workstation evaluation.

4.2. Musculoskeletal Complaints Based on Nordic Body Map

The results of the Nordic Body Map (NBM) questionnaire showed that five out of six operators (83.3%) were classified as having a low level of musculoskeletal risk, while one operator (16.7%) was classified as having a moderate risk level. A summary of the NBM assessment results is presented in Table 1.

Table 1: Nordic Body Map (NBM) Results

Operator	NBM Score	Risk Category
Operator 1	37	Low
Operator 2	34	Low
Operator 3	59	Moderate
Operator 4	30	Low
Operator 5	38	Low
Operator 6	32	Low

The most frequently reported areas of discomfort were the waist, lower back, and buttocks. However, the majority of reported complaints were categorized as mild and did not significantly interfere with daily work activities. No operators were classified in the high-risk category based on the NBM assessment.

These findings indicate that, based on subjective self-reports, most operators did not yet experience severe musculoskeletal symptoms during their routine work activities.

4.3. Ergonomic Risk Assessment Based on Rapid Office Strain Assessment

In contrast to the NBM results, the Rapid Office Strain Assessment (ROSA) revealed a different pattern of ergonomic risk. All six operators obtained final ROSA scores

greater than 5, indicating a high level of ergonomic risk that requires corrective action. The distribution of ROSA scores and corresponding risk interpretations is shown in Table 2.

Table 2: Rapid Office Strain Assessment (ROSA) Results

Operator	Final ROSA Score	Risk Interpretation
Operator 1	6	High risk
Operator 2	8	High risk
Operator 3	8	High risk
Operator 4	8	High risk
Operator 5	7	High risk
Operator 6	7	High risk

Analysis of individual ROSA components showed that the work chair contributed most significantly to the overall ROSA score. The main issues identified included:

1. Inappropriate seat height relative to operator body dimensions,
2. Insufficient backrest support, particularly in the lumbar region,
3. Limited adjustability of chair components to accommodate different operator anthropometry.
4. Monitor height and keyboard–mouse placement also contributed to ergonomic risk, although to a lesser extent compared to chair-related factors.

4.4. Comparison Between NBM and ROSA Results

A notable discrepancy was observed between subjective musculoskeletal complaints (NBM) and objective ergonomic risk assessment (ROSA). While most operators reported low levels of discomfort, objective assessment indicated that all workstations were ergonomically inadequate.

This discrepancy suggests that although musculoskeletal symptoms were not yet severe, operators were exposed to latent ergonomic risks that may increase the likelihood of developing musculoskeletal disorders if corrective measures are not implemented.

5. Discussion

The results of this study reveal a clear contrast between subjective musculoskeletal complaints and objective ergonomic risk levels among control room operators. While the Nordic Body Map assessment indicated generally low levels of reported discomfort, the Rapid Office Strain Assessment identified high ergonomic risk across all evaluated workstations.

This discrepancy suggests the presence of latent ergonomic risks, where non-ergonomic workstation conditions exist without immediately causing severe musculoskeletal symptoms. Operators may adapt to prolonged static postures or underreport early discomfort, particularly in environments where prolonged sitting is perceived as a normal aspect of work. However, sustained exposure to such conditions may increase the risk of developing chronic musculoskeletal disorders over time.

The work chair emerged as the dominant contributor to ergonomic risk. Limited seat height adjustability and inadequate backrest support restrict operators' ability to maintain neutral sitting postures during extended monitoring tasks. Prolonged sitting without sufficient lumbar support has been widely associated with increased spinal loading and muscle fatigue. These findings align with previous ergonomic studies emphasizing the critical role of seating design in computer-based work environments.

Interestingly, the operator classified as having moderate musculoskeletal risk based on NBM did not necessarily correspond to a distinctly higher ROSA score. This indicates that musculoskeletal complaints are influenced by individual factors such as physical condition, work adaptation, and tolerance to discomfort, in addition to workstation design. Consequently, relying solely on subjective complaint data may underestimate actual ergonomic risk.

The combined application of Nordic Body Map and Rapid Office Strain Assessment in this study provides a more comprehensive evaluation of ergonomic conditions. While NBM captures workers' perceived discomfort, ROSA objectively identifies workstation design deficiencies that may not yet manifest as symptoms. This integrated approach supports preventive ergonomic strategies aimed at reducing long-term musculoskeletal risk.

The findings of this study further support the notion that ergonomic risk should be viewed as an integral part of work system evaluation in industrial operations. Although subjective musculoskeletal complaints among operators were relatively low, the consistently high ROSA scores indicate latent ergonomic risks that may affect long-term performance and system reliability. This observation is consistent with previous work by Padhil *et al*. (2024) [8], which emphasized that improvements in work systems, including physical work conditions, are essential for sustaining productivity and preventing performance degradation in industrial environments.

Overall, the findings highlight the importance of early ergonomic intervention in control room environments. Improving seating design and workstation adjustability is essential to reduce ergonomic risk, prevent musculoskeletal disorders, and enhance operator comfort and productivity.

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