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Ergonomics Risk Factors Analysis of Building Construction Work in SARBAGITA Region Bali Indonesia

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Abstract

The main objective of this research is to analyze Ergonomics Risk Factors and MSDs Rate in building construction work in the SARBAGITA area of Bali, Indonesia. SARBAGITA, an acronym for Denpasar, Badung, Gianyar, and Tabanan, is the largest metropolitan area in the Nusa Tenggara Islands and the second largest in the Eastern Indonesia Region after the metropolitan city of Mamminasata in South Sulawesi. Therefore, various infrastructure facilities have been developed, including office buildings, hotels, and other public facilities. The development of infrastructure in the SARBAGITA can be seen through the number of active construction companies. In 2020, the number of active construction companies was 987, decreased slightly during the COVID-19 pandemic in 2021 to 883, and rose again to 997 in 2022. If each company has at least one construction project, then the number of active projects in 2022 was 997. Construction work is very complex, especially in building construction. Involving a large number of workers with varied backgrounds, most of the work is carried out outdoors, using a variety of heavy-duty equipment, and involving hazardous materials. Construction work has a high risk of accidents and work-related diseases from aspects of biology, physics, chemistry, ergonomics, and even psychology. This study focuses more on ergonomics aspects, determines ergonomic hazards, and analyzes ergonomic risk factors (ERF) and MSDs in the SARBAGITA area with 500 subjects of construction workers, including 50 female workers (10%). Measurements were carried out based on the Indonesian National Standard SNI 9011:2021. The results showed that ergonomic risk factors were in the dangerous category with a mean score of 36.84 (>>>7), requiring immediate action to improve working conditions. Meanwhile, the MSDs risk level is also in a high-risk category with an average score more than 12, including the low back MSD with the average score of 13.98, followed by the calf (12.41), shoulders (11.57), and (12.23). Meanwhile for the neck, elbows, back, hands, thighs, knees, and feet are in the medium risk category with a score between 6 - 8. It is recommended to do the ergonomics intervention on the work conditions and environment to reduce the risk of occupational safety and health.

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1 Introduction

In line with the movement of the industrial revolution from 1.0 to 4.0, the characteristics of human work activities have also shifted. From being completely manual in the industrial era 1.0 to completely automatic through the development of smart technology in the industrial era 4.0. This is, of course followed by a change in the potential for accidents and occupational diseases.

In the industrial era 1.0 between 1760 – 1840, when steam engines were just beginning to be developed, most of the work was still done manually with traditional work tools. The steam-powered technology using coal as raw material, which is starting to be developed, is generally used for the textile industry in England. Furthermore, steam technology began to be developed for agriculture, mining, transportation, and manufacturing. Several parts of the work process that are usually carried out manually are replaced by machines using steam resources. In this industrial era 1.0, it is certain that the work accidents due to electric current were still very low or non-existent, while work accidents and illnesses caused by the operation of steam exposure machines were starting to appear. From the ILO database, several types of potential hazards that can cause work accidents related to the operation of steam engines or boilers include falls from ladders or heights, slips and falls, and mechanical accidents when operating pulverizers and stokers on coal-fired boilers. Burns due to surface damage, heat, hot water and steam, electric shock, poisoning by carbon monoxide or other combustion products in the air, which can cause acute carbon monoxide poisoning, headache, dizziness, nausea, unconsciousness, coma, and even death, and asphyxia due to breathing air oxygen deprivation (Eurostat, 2023; Narayanan et al., 2023; Rajendran et al., 2021; Stefana et al., 2021). In the industrial era 2.0, between 1879 – 1970, electric power began to be developed. Various technologies that use electric power are starting to be developed with the main aim of increasing machine operational efficiency in various fields. In the industrial era 2.0, there have been major changes. Automotive factories began to appear, and most human labor began to be replaced by machine power. Furthermore, in the industrial era 3.0 in the early 1970s, automation technology began to be developed. In this era, mass production systems for various manufactured goods began to be developed. In the era of technology that uses electrical resources, the main potential dangers are electric shock and burns due to contact with live parts, injuries due to exposure to sparks, fires from damaged electrical equipment or installations; explosions caused by unsuitable electrical equipment or static electricity that ignites flammable vapors or dust, and electric shocks that can cause other injuries such as falls from ladders or scaffolding (Antwi-Afari et al., 2019; Kulor et al., 2024; Tripathi & Mittal, 2024). From the industrial era 2.0 to the industrial era 3.0, the potential causes of accidents and occupational diseases have also shifted. In the industrial era, 1.2 and 1.3. Work-related accidents and illnesses were predominantly physical, caused by workload and work environment. This is different from the potential causes of accidents in the industrial era 1.3, where computer and software-based smart technology is prioritized. Workers are more required to carry out cognitive tasks, using more thinking, even though physical work still exists. Therefore, the potential causes of work-related accidents and illnesses are also shifting or increasing, not only caused by physical work burdens or the physical work environment, but also affecting the psychological realm. Various psychological disorders due to work began to emerge, which also had an impact on the emergence of various accompanying diseases (Santiana et al., 2024).

The ILO report in 2015 shows that the global trend of work-related accidents and illnesses has changed. The results of the analysis of the number of accidents and illnesses due to work show that fatal illnesses due to work dominate compared to fatal accidents due to work. Work-related fatal illnesses account for 86% while work-related fatal accidents account for 14%. The type of accident and illness that requires the most expensive compensation and requires a long healing or recovery time is Musculoskeletal Disorders (MSDs), which reaches 40% of total compensation costs, followed by heart and circulatory diseases (16%), work accidents (14%), respiratory disorders (9%), central nervous system disorders (8%), tumors and skin 3% each. Furthermore, what about the industrial era 4.0? In the industrial era 4.0, the implementation of which was accelerated by the COVID-19 conditions, workers can carry out their duties from various places. The characteristics of the industrial era 4.0 are that workers are required to carry out their tasks quickly, precisely, accurately, with quality, multitasking, and have almost no

working time limits. As a result, in addition to physical fatigue, many workers begin to experience greater psychosocial pressure (Haleem et al., 2024; Veile et al., 2022). From the data above can be generalized that the relationship between potential sources of danger and the types of accidents and occupational diseases is closely related to technological progress and development. However, this does not seem to apply to the construction industry. In all industrial revolutions from 1.0 to 4.0, the potential hazards in the construction industry still cover all aspects from biology, chemical, and physics. ergonomics and psychology. Therefore, it is very natural that for several decades, the construction industry has been in the top three contributing to the high number of fatal work accidents, alongside the transportation and manufacturing sectors.

The European Commission reported that the sector that contributed to the highest number of fatal work accidents was still construction. followed by manufacturing, transportation, agriculture, and wholesale and retail trade as described in Figure 1 (European, 2024).

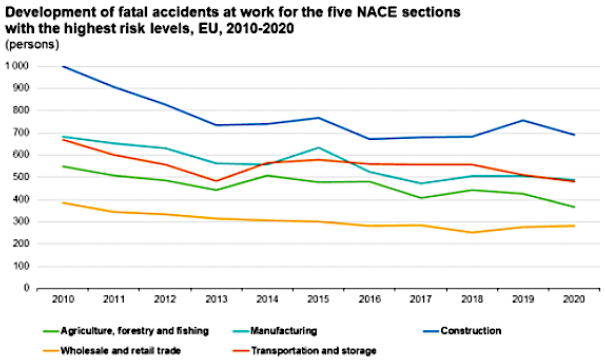

Figure 1. Trends of fatal accidents at work with high-risk levels in the European Union (European, 2024)

In line with the European Commission report, the National Safety Council (NSC) USA also reported that the 5 most dangerous sectors with fatalities are agriculture, transportation, mining, construction, and wholesale trade (National Safety Council USA, 2023). The European Union and the USA are developed countries whose governments and societies are advanced and care about occupational safety and health. but it turns out that the number of accidents and fatal illnesses due to work is still high. What about Asian countries?

Construction work in China has long been the most dangerous sector, and according to official government statistics, construction work has become increasingly dangerous, so that in July 2018, the Government established the Ministry of Emergency Management (MEM) (Chen et al., 2020). The high-risk sectors in Japan are forestry, mining, construction, transportation, and cleaning (Hayashi et al., 2023). The highest number of 2021 occupational injuries in Malaysia was recorded in the Manufacturing sector at 7.994 cases, followed by services (4.299 cases), construction (2.297 cases), and wholesale and retail trade (1.979 cases) (Zermane et al., 2023). The National Statistic Ministry of Manpower Singapore reported that in 2022, the construction sector contributed the highest number of fatal and major injuries (171 cases), followed by manufacturing (129 cases), and transportation and storage (70 cases) (Ministry of Manpower (Singapore), 2022). From data related to dangerous sectors in Japan, China, Malaysia, and Singapore, the construction sector remains in the top 3 industries that contribute to work-related fatal accidents and diseases, then how about Indonesia?

Legislation related to occupational safety and health in Indonesia has existed since the Dutch colonial era, then after independence, it was expressed through Law Number 1 of 1970 concerning Work Safety, which was subsequently issued in the form of government regulations, presidential regulations, ministerial regulations, and ministerial decisions. It was even indicated by a UN/ILO representative that the laws and regulations relating to occupational safety and health in Indonesia are the most complete. Unfortunately, its implementation and supervision are far less than neighboring countries, so the number of accidents and work-related illnesses in Indonesia is still high. The statistical data related to occupational safety and health that are officially published by the government from the central to provincial and district/city levels are still difficult to obtain. In general, information related to work accidents can be obtained from print or electronic media. For example, news published in the online media Kumparan Bisnis on June 22, 2023. The Indonesian Minister of Manpower, Dr. Hj. Ida Fauziyah. M.Si. in her speech said that the number of work accidents, including occupational diseases, in 2020 was 221,740 cases, increasing in 2021 to 234,370 cases, and in 2022 increasing quite large to 298,137 (KumparanBISNIS, 2023).

Several media outlets reported that the construction industry contributed the highest number of work accidents. Construction Media reports that the construction sector is in first place in contributing to the number of work accident cases, reaching 32% of the total work accident cases in Indonesia. The second position is the manufacturing industry sector, which reached about 31.6%, followed by the transportation sector (5.3%), forestry (3.8%), and mining (2.6%) (Badriyah et al., 2022). This data still focuses on work accidents; what about the data on work-related illnesses? Work-related illness numbers in Indonesia are still difficult to obtain. However, the government's attention through the Ministry of Manpower still shows that there is attention to occupational diseases, especially related to Musculoskeletal Disorders (MSDs), which are the occupational diseases that rank first, requiring long recovery times, and the highest health compensation costs in various countries. This is marked by the establishment of Minister of Manpower Regulation number 5:2018 concerning Occupational Safety and Health in the Work Environment and Indonesian National Standard number 9011:2021 concerning Measurement and Evaluation of Ergonomic Hazards in the Workplace and the MSDS Risk Category. Through these two regulations, the potential dangers of the ergonomics aspect began to be discussed in detail and disseminated in various industries. This research tried to implement those two regulations and standards with the main objective is to analyzing Ergonomics Risk Factors and MSDs Risk in building construction work in the SARBAGITA area of Bali, Indonesia. Through this research, it is hoped that a general picture can be obtained about the potential for occupational hazards and diseases from the ergonomics aspect, especially for the construction sector.

2 Materials and Methods

This research was conducted in the SARBAGITA region, which includes Denpasar, Badung, Gianyar, and Tabanan regencies as the metropolitan city of Bali Province, which has about 987 active construction industries. The research was conducted by a descriptive quantitative design with 500 subjects, including 50 female subjects (10%). The object of the research was the active projects of multi-level buildings with at least 3 levels. Two kinds of questionnaires from the National Indonesian Standard SNI 9011:2021 were distributed to all the subjects. The first questionnaire is to measure the MSD risk. From this questionnaire, the average data of the frequency and level of severity can be obtained. The second questionnaire contain of 43 questions about any kinds of working postures and working loads, including lifting and carrying activities) (Adiratna et al., 2022; Elsa Dwi et al., 2024). To ensure subjects fulfil the questionnaire correctly. surveyor coached and lead the subject in describe their feeling and their work postures or working mobility. Result of the questionnaire for the MSDs risk then categorize based on the matrix as described in Table 1.

Table 1
MSDs Risk Category

Frequency	Severity			
	Non (1)	Inconvenient (2)	Pain (3)	Painful (4)
Never (1)	1	2	3	4
Sometimes (2)	2	4	6	8
Often (3)	3	6	9	12
Always (4)	4	8	12	16

High risk Medium risk Low risk

The result of the second questionnaire (attachment D SNI 9011:2021) was then summarized as described in Table 2 (attachment C SNI 9011:2021).

Table 2
Result of ergonomics assessment (attachment C SNI 9011:2021)

No.	Department/ unit/room	Type of job	Result of Assessment			Total score	Interpretation	Recommendation
			Upper body	Back/low back	Manual Lifting/carrying			
..	…	…	…	…	…	…	…	…
..	…	…	…	…	…	…	…	…

3 Results and Discussions

3.1 Result

Subject Characteristic
Subject characteristics are described in Table 3.

Table 3
Subjects Characteristic

Regency	Number of subjects (n)			Age		Work Experience	
	Male	Female	n	Average	SD	Average	SD
Denpasar	135	15	150	38.87	9.42	7.92	4.19
Badung	135	15	150	38.07	10.73	5.63	2.67
Gianyar	90	10	100	37.97	10.18	5.25	5.26
Tabanan	90	10	100	38.27	10.56	4.21	1.84
Total Amount	450	50	500	153.18	40.89	23.01	13.96
Average				38.29	10.22	5.75	3.49

Ergonomics Risk Factors

Assessment of the potential Ergonomics Risk Factors (ERF) is carried out using a checklist (SNI 9011:2021 Appendix B). The assessment begins by conducting preliminary observations of a job to determine the hazard factors. The checklist is to identify the combination of hazard factors that cause the highest or most frequent risks in an industrial environment (Adiratna et al., 2022; Elsa Dwi et al., 2024). Assessment was divided into three parts, including upper body, back, and lower body, lifting and carrying a load manually as described in Table 4.

Table 4
Analysis of Ergonomics Risk Factors

Regency	Upper Body	Back and lower body	Lifting-carrying load manually	Total Score	Category of ERF
Denpasar	14.13	11.68	10.56	36.37	Dangerous (> 7)
Badung	20.75	15.77	12.02	48.53	Dangerous (> 7)
Gianyar	10.69	11.28	10.29	32.26	Dangerous (> 7)
Tabanan	16.35	17.35	13.41	47.11	Dangerous (> 7)
Total	61.92	56.08	46.28	164.27	
Average	15.48	14.02	11.57	41.07	Dangerous (> 7)

MSDs Risk

Musculoskeletal Disorders (MSDs) are complaints of pain or soreness due to injuries and disorders of muscles, tendons, joints, nerves, and other soft tissues. The main causes of MSDs are manual lifting and carrying loads in awkward posture, repetitive work, long working hours, and poor working conditions. All of these main causes are part of the characteristics of construction work; therefore, the risk of MSDs in the construction industry is very high, as described in Table 5.

Table 5
Analysis of MSDs Risk

Body parts	Denpasar	Badung	Gianyar	Tabanan	Total score	Average score
	Score					
Neck	5.55	6.4	6.38	6.4	24.73	6.18
Shoulder	12.06	12.09	9.95	12.18	46.28	11.57
Elbow	6.25	6.43	6.16	5.95	24.79	6.20
Back	6.69	5.95	5.76	6.4	24.8	6.20
Arm	12.23	12.2	12.5	11.97	48.9	12.23
Low-back	14,21	14,67	14,21	12,82	55.91	13.98
Hand	6.37	6.18	5.81	6.71	25.07	6.27
Hips	5,49	6,5	6.74	6.73	26.46	6.62
Thigh	6.45	6.15	6.18	6.08	24.86	6.22
Knee	5.73	5.89	6.81	5.59	24.02	6.01
Calf	12.32	12.37	12.57	12.39	49.65	12.41
Feet	6.21	6.21	6.2	6.97	25.59	6.40

3.2 Discussion

The subject average age is about 39.295 + 10.22, and the work experience is 5.75 + 3.49. Several studies show that age and experience are correlated with the risk of work accidents. The risk of work accident claims peaks in workers aged 25-44 years and weakens further in workers aged 45 years and over (Kearney et al., 2023). Young male workers aged 24 years or less had the highest rate of fatal occupational injuries (Park et al., 2024). Research in construction sites in Iran showed that the ages and working experience were 29.18 ± 7.67 and 4.67 ± 3.9 years, and had a significant association with accident rates (Karimi & Taghaddos, 2019). In line with those studies, it is reported that the ages and experiences were also strongly associated with the accident rates in construction work in Indonesia (Bria et al., 2024; Sudiajeng et al., 2023). From the aspects of ergonomics and work physiology, worker characteristics, including age and work experience, influence work behavior, becoming one of the factors that influence the number and level of work-related accidents and diseases.

Table 4. The ERF of the works for all aspects of parameters in all regions of SARBAGITA was in the dangerous category, with an average total score of 41.07. Means that the working conditions require immediate improvement. The ERF score of the upper body was the highest, with the average score being 15.48. It includes the assessment of the working posture and or movement related to the head and neck, shoulders, arm, wrist (question numbers 1 to 16, SNI 9011:2021). The assessment of the back and lower body was related to the working posture and movement, including forward and backward bending, twisting, squatting, kneeling, tiptoe, lifting legs forward/backward (questions 17 to 33, SNI 9011:2021). The result showed the ERF for the back and lower body was 14.02. ERF for lifting-carrying loads was assessed based on the lifting working posture, load weight, and the distance of movements (questions 34 to 43, SNI 9011:2021).

A Literature Review of Ergonomics Risk Factors in the Construction Industry listed the ERF in the construction industry as: 1) Awkward Posture; 2) Force; 3) Repetition; 4) Vibration; 5) Static Loading; 6) Contact Stress; 7) Extreme Temperature (Belay et al., 2024; Jones, 2019). The assessment of ERF in the construction industry in Malaysia found out that the most critical ERFs are extreme hot temperature, leaning forward/side, twisting the back,

and Organizational factors (Chen & Yu, 2024; Tandazo et al., 2025). From the results of this research, it was proven again that construction work is very complicated, involves big number of workers with various backgrounds, heavy equipment, hazardous materials, and exposure to a hazardous environment, and all of these working conditions are factors that cause ergonomic risks.

Table 5 presents the result of MSDs risk in the construction industry in the SARBAGITA region, Bali, Indonesia. Refers to SNI 9011:2021, the MSDs risk is categorized into three levels: low risk with a score of 1 – 4; medium risk with a score of 6, and high risk with a score of 8 – 16 Table 1). The scores in Table 5 are all > 4, and the highest score of MSDs in all regencies with high-risk category (MSDs score is 9 – 16) was for the low back with the average score of 13.98, followed by the calf (12.41), shoulders (11.57), and arm (12.23). Meanwhile, other body parts such as the neck, elbows, arms, back, waist, knees, and feet are in the moderate risk category towards high risk with an MSDs score > 6. MSDs complaints in the low back, calf, and feet are caused by construction work being mostly carried out in a standing work posture with long working hours. The research about work-related MSDs among dentists found that MSDs are significantly associated with the standing working posture (Dianat et al., 2020; Joshi & Deshpande, 2021; Yusuf et al., 2025; Yusuf et al., 2024). Construction workers who carry out their tasks manually have a high risk of developing work-related musculoskeletal disorders, and there is a significant relationship between work duration and symptoms of MSDs in construction workers on the worker's lower body (Tandazo et al., 2025; Yusuf et al., 2024).

MSDs are the work-related illnesses that are currently the most frequently reported. MSDs cause high levels of absenteeism, decreased self-confidence, productivity, and income, require long recovery times, and high health compensation costs. Some researchers reported that in developed countries, MSDs account for up to 30% of all injuries requiring time away from work (Belay et al., 2024; Chan et al., 2022; Suarbawa et al., 2024). Apart from work posture, age also greatly influences the potential risk of MSDs. Other studies state that older workers have a higher potential risk than young workers because, physiologically, young adults have prime muscle strength and reach their peak at the age of 33 years (Dropkin et al., 2019; Kaur et al., 2023; Tyrdal et al., 2024). From the results of this study, which are also in line with other similar studies, it can be concluded that the characteristics of construction work are all related to the potential risk of MSDs.

4 Conclusion

Results and discussion supported by various references of similar research, it can be concluded that construction work, with its very complex characteristics, involving relatively large numbers of workers, various types of work carried out manually and mechanically over a long period of time, is closely related to the potential risk of MSDs. This research with 500 subjects actively working in the ongoing building construction project found out that ERF of the works for all aspects of parameters in all regions of SARBAGITA was in the dangerous category, with the average total score of 41.07. ERF score of the upper body was the highest with the average score of 15.48, which includes the assessment of the working posture and or movement related to head and neck, shoulders, arm, wrist. ERF of the back and lower body related to the working posture and movement, including forward and backward bending, twisting, squatting, kneeling, tiptoe, lifting legs forward/backward) was also in the dangerous category with an average total score of 14.02. Moreover, from the aspect of manual lifting – carrying load also in the dangerous category with the average total score of 11.57.

In line with the ERF category, the MSDs risk was in the high-risk category with the average score > 8. The highest score of MSDs in all regencies with high-risk category was for the low back with the average score of 13.98, followed by the calf (12.41), arm (12.23), and the shoulders with the average score of 11.57. Meanwhile, other body parts such as the neck, elbows, arms, back, waist, knees, and feet are in the moderate risk category towards high risk with an MSDs score >6.

From the results and discussions, which are reinforced by various references, it can be concluded that building construction work has ERF in the dangerous category and MSDs risk in the high-risk category. This means an immediate improvement in working conditions is needed. Further research in the form of ergonomic interventions to improve working conditions that can reduce ERF levels and the risk of MSDs is needed.

Conflict of interest statement
The authors declared that they have no competing interests.

Statement of authorship
The author(s) have a responsibility for the conception and design of the study. The author(s) have approved the final article.

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