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Analysis of the Correlation Between Occupational Accidents and the Severity of Head Injuries at RSU Royal Prima Medan

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Abstract

Head injuries resulting from occupational accidents are a significant cause of morbidity and mortality among working-age individuals. However, research examining the association between occupational injury mechanisms and head injury severity in Indonesia remains limited. This study aimed to examine the association between occupational accident mechanisms and head injury severity at Royal Prima General Hospital in Medan, Indonesia, and to compare Glasgow Coma Scale (GCS) scores between patients with and without preexisting comorbidities. An analytical cross-sectional study was conducted using medical records from January 2024 through December 2025. The study included 60 patients categorized into an inclusion group (n = 30) and an exclusion group (n = 30). Data were analyzed using the Mann–Whitney U test, Fisher's exact test, and binary logistic regression. The proportion of moderate-to-severe head injuries was higher among patients exposed to high-energy injury mechanisms (33.3%) than among those exposed to low-energy mechanisms (6.7%), although the association was not statistically significant (p = 0.169; odds ratio [OR] = 7.00). Patients in the exclusion group had significantly lower GCS scores (p = 0.020; r = 0.301). After adjustment for sex, patients with preexisting comorbidities had higher odds of moderate-to-severe head injury (OR = 4.79; 95% confidence interval [CI]: 1.47–15.62; p = 0.009). Subgroup analysis identified a significant association between diabetes mellitus and head injury severity (OR = 6.00; p = 0.012), whereas hypertension showed no statistically significant association. In conclusion, occupational injury mechanisms were not significantly associated with head injury severity in this sample, whereas preexisting comorbidities, particularly diabetes mellitus, were associated with greater injury severity. These findings highlighted the importance of considering comorbidities when interpreting GCS scores and assessing patients with occupational head injuries in emergency care settings.

INTRODUCTION

Head injuries, including traumatic brain injuries (TBIs), represent a major global public health concern. The World Health Organization (WHO) has highlighted the substantial burden of traumatic injuries, which contribute to mortality and long-term disability among working-age populations (WHO, 2021). Beyond their clinical consequences, occupational head injuries can impose considerable socioeconomic burdens on affected individuals and their families, particularly when disability reduces earning capacity and household financial stability.

Occupational accidents also contribute substantially to global morbidity and mortality. According to the International Labour Organization, (2023), approximately 2.93 million workers die annually from work-related causes, highlighting the continuing importance of occupational safety and health. In Indonesia, occupational injury compensation and employment-related social security benefits are administered through BPJS Ketenagakerjaan. Reported benefit payments amounted to approximately IDR 52.72 trillion in 2023 and IDR 49.03 trillion in 2024 (Arif Ferdianto, 2024).

Workers in high-risk sectors, particularly construction and manufacturing, face substantial risks of occupational injuries, including head trauma. Common injury mechanisms include falls from heights, impacts from falling objects, collisions with heavy equipment, and work-related transportation accidents (Awaluddin et al., 2023).

Patients with suspected head injuries typically undergo initial assessment and triage in the emergency department (ED), where prompt evaluation is essential for identifying potentially life-threatening neurological conditions. The Glasgow Coma Scale (GCS) is widely used to assess the level of consciousness following traumatic brain injury through eye-opening, verbal, and motor responses. Based on GCS scores, TBI severity is commonly categorized as mild (13–15), moderate (9–12), or severe (3–8) (Tsao, n.d.). Although the GCS provides a standardized assessment of neurological responsiveness, its interpretation must account for clinical factors that may affect consciousness independently of the traumatic injury.

In emergency clinical practice, GCS scores may be influenced not only by the severity of traumatic brain injury but also by preexisting medical conditions and other factors affecting neurological responsiveness. Hypertension, diabetes mellitus, and acute alcohol intoxication may complicate the clinical assessment of patients with head injuries, although their mechanisms and effects differ. Salehpour et al. (2015), in research published in Turkish Neurosurgery, and retrospective analyses of trauma registry data have examined associations between vascular or metabolic comorbidities, admission GCS scores, and functional outcomes measured using the Glasgow Outcome Scale–Extended (GOSE). These findings raise an important clinical question regarding whether reduced consciousness reflects the primary traumatic injury, associated physiological disturbances, or a combination of both.

Several pathophysiological mechanisms may explain the relationship between comorbidities and neurological outcomes following head trauma. First, chronic hypertension may contribute to cerebrovascular remodeling and impaired cerebral autoregulation, potentially increasing vulnerability to secondary neurological complications following traumatic injury (Dhandapani et al., 2012). Second, diabetes mellitus and associated disturbances in glucose regulation may complicate TBI outcomes. Stress-induced hyperglycemia has been associated with metabolic dysfunction, cerebral edema, and secondary neuronal injury. Shi et al. (2016), in a study published in Oncotarget, reported an inverse correlation between admission blood glucose concentrations and GCS scores, indicating that higher glucose levels were associated with lower levels of neurological responsiveness. However, this association does not establish that preexisting diabetes directly caused the observed reduction in GCS scores. Third, acute alcohol intoxication may depress central nervous system (CNS) activity and alter verbal and motor responses, potentially complicating GCS interpretation. Although some large-scale studies have reported relatively small average

effects of alcohol intoxication on GCS scores (Stuke et al., 2007; Rundhaug et al., 2015), caution remains necessary when assessing neurological status in intoxicated patients.

To examine these potential influences, patients with occupational head injuries were categorized into two groups: an inclusion group comprising patients without the specified potential confounding conditions and an exclusion group comprising patients with comorbidities or other characteristics meeting the study's exclusion criteria. GCS scores were compared between the groups to assess differences in neurological presentation and determine how the application of exclusion criteria affected the characteristics of the analyzed sample. This comparison also provided preliminary evidence regarding associations between comorbidities and head injury severity, although it could not independently establish causal effects or confirm statistical confounding.

In Indonesia, research specifically examining the association between occupational accident mechanisms and head injury severity remains limited. Existing studies have primarily addressed occupational accident epidemiology, injury prevention, or the general clinical management of head trauma. Comparatively fewer studies have examined how specific occupational injury mechanisms, such as falls and impacts from objects, are associated with GCS-based severity classifications among patients receiving hospital treatment.

Occupational accidents may result from interactions among human factors, workplace conditions, operational processes, equipment, and external hazards. Human factors may include unsafe behaviors, errors, physical limitations, and psychosocial conditions (Rigit et al., 2025). In Indonesia, the Ministry of Manpower recorded 462,241 occupational accident cases in 2024, including 23,739 cases in North Sumatra (SDI Employment Priority Data 2024, 2024; Tsao, 2020). Occupational injuries may result in physical disability, reduced work capacity, financial hardship, and disruption of family responsibilities, while delays in appropriate treatment may increase the risk of adverse clinical outcomes (Marco et al., 2023). Against this background, the present study examined the association between occupational accident mechanisms and GCS-based head injury severity among patients treated at Royal Prima General Hospital in Medan. It also investigated whether sex and age were associated with injury severity and whether GCS scores differed between patients without the specified potential confounding conditions and those with comorbidities, acute alcohol intoxication, or a history of referral from another hospital.

This study aimed to examine the association between occupational accident mechanisms and head injury severity among patients treated at Royal Prima General Hospital in Medan and to compare GCS-based severity profiles between patients with and without the specified potential confounding conditions. Specifically, the study sought to describe the frequency and severity distribution of occupational head injuries in the available medical records, evaluate associations between injury mechanisms and GCS-based severity classifications, and compare GCS score distributions between the inclusion and exclusion groups. The findings were intended to provide preliminary clinical evidence to support more comprehensive neurological assessments, inform emergency department triage practices, and contribute to occupational injury prevention efforts. Because the study was based on hospital medical records, its findings were not intended to estimate the population-level prevalence of occupational head injuries or establish causal relationships between comorbidities and neurological outcomes.

METHOD

Research Design

This study employed a quantitative approach using an analytical cross-sectional observational design to examine associations between variables without longitudinal follow-up (Wang & Cheng, 2020).

Population and Sample

The study population was a victim of a work accident who came to Royal Prima Medan Hospital with a decrease in consciousness due to head injuries, with mechanisms such as falling from height, traffic accidents, and being hit by blunt objects. Samples were taken from medical records for the period January 2024 to December 2025, and the initial survey obtained 60 samples.

Inclusion criteria include patients with a primary diagnosis of head injury due to a work accident (falling from a height or being hit by a heavy weight) who are treated at Royal Prima Hospital, of productive age, and have a complete medical record (age, gender, GCS score, type of occupation). Exclusion criteria include injuries due to non-occupational incidents; damaged, missing, or no initial GCS score; neurological diseases (stroke, brain tumors, epilepsy); degenerative diseases such as diabetes mellitus; the influence of alcohol or psychotropic substances; treatment in other facilities prior to GCS measurements; multiple injuries with hypovolemic shock; and DOA (dead on arrival) patients.

Variables and Data Coding

The dependent variable was the severity of the head injury based on the first GCS score in the emergency room (mild 13–15, moderate 9–12, severe 3–8), which for analysis was grouped into mild and moderate–severe. The main independent variables were the mechanism of work accidents (high energy and low energy), with sex (male, female) and age (early adulthood, intermediate adulthood) as the controlling variables. All data were obtained from medical records and converted to numerical form for ease of processing.

Data Analysis

Univariate analysis. Categorical data are presented as frequencies and percentages ($P = f/n \times 100\%$). Numerical data (age and GCS score) are presented as averages ± standard deviations when distributed normally, or medians and interquartile ranges if not, accompanied by minimum and maximum values. Prerequisite test. Normality is tested with Shapiro-Wilk because the number of subjects per group is less than 50, performed separately in each group ($p > 0.05$ means normal). The GCS score has an upper limit of 15 so the distribution tends to be skewed to the left; this is the nature of the instrument, so non-parametric tests have been anticipated since design. The homogeneity of the variant is tested with Levene as a complement only, since the determinant of the selection of the main test is the result of normality.

Bivariate analysis. The comparison of GCS scores between the two groups used the Mann-Whitney U test when the data were abnormal, with the unpaired t-test only as a comparator when the data were normal and the variant was homogeneous. This test was chosen because the two groups were independent of each other and the GCS was essentially ordinal. The results were presented as the median and interquartile ranges, with U, Z, p, and magnitude values of $r = |Z|/\sqrt{N}$ (0.1 small; 0.3 medium; 0.5 large). The relationship between categorical variables was tested with Pearson's Chi-square ($\chi^2 = \Sigma[(O - E)^2/E]$) when the entire expected

frequency was ≥ 5, and with Fisher exact when there were cells with an expected frequency of < 5. In addition to the p value, the Odds Ratio (OR) with a confidence interval (CI) of 95% was reported; meaningful relationship when CI does not pass 1. In tables with zero values, the Haldane-Anscombe correction is used (the addition of 0.5 to each cell).

Multivariate analysis. Binary logistic regression is used to assess whether relationships remain meaningful after controlling for confounding variables, since dependent variables are dichotomous (linear regression is inappropriate because it does not meet residual assumptions and can produce conjecture values outside the range of 0–1). The model is $\ln[p/(1-p)] = \beta_0 + \beta_1 X_1 + ... + \beta k Xk$, with adjusted OR = exp(β). The candidate variable is one that has $p < 0.25$ in bivariate analysis, with a limit on the number of variables following the rule of at least 10 events per independent variable (EPV). Since there were only 22 subjects with moderate–severe head injuries, a maximum of two variables were included, using the Enter method because this study tested a predetermined hypothesis, not an exploratory one. The significance of the coefficient was tested with Wald statistics, and the results were reported as B, SE, Wald, p, adjusted OR, and 95% CI. Confounding was judged from the change in the estimation, i.e. adjusted |OR − gross OR|/gross OR × 100%; when it exceeded 10%, the variable was declared confounding and the adjusted model was reported as the main result, even though the variable itself was not statistically significant.

Subgroup and sensitivity analysis. From the beginning, subgroup analysis based on the reason for exclusion was determined, because the reason for exclusion was different in nature (comorbidities versus conditions that were indeed accompanied by decreased consciousness), as well as sensitivity analysis to the categorization of accident mechanisms that were repeated in three scenarios, considering that half of the mechanism records were only in the form of general terms. This pre-determination prevented the impression of searching for data after the results were known.

Level of Meaning and Presentation of Results

All tests used a significance level of 0.05, 95% confidence, and two-direction. The p-value was reported three digits after a comma ($p < 0.001$, instead of 0.000), each OR was accompanied by a CI of 95%, each test was different with a magnitude of influence, and the decimal separator used a comma consistently.

RESULTS AND DISCUSSION

Test Analysis Requirements

1. Shapiro-Wilk normality test

The Shapiro-Wilk normality test was performed separately on each group, not on the combined data. The test results are presented in Table 1.

Table 1 Shapiro-Wilk normality test results

Variable	Groups	n	W Stats	Value p	Conclusion
GCS Score	Inclusions	30	0,688	< 0.001	Abnormal
	Exclusion	30	0,877	0,002	Abnormal
	High energy mechanism	15	0,804	0,004	Abnormal
	Low energy mechanism	15	0,674	< 0.001	Abnormal
Age	Inclusions	30	0,969	0,511	Normal
	Exclusion	30	0,923	0,031	Abnormal

Table 1 shows that GCS scores were not normally distributed across the tested groups, with an overall p-value of less than 0.05. Therefore, as per the decision-making basis in Chapter III, the differential test for GCS scores used the non-parametric Mann-Whitney U test as the primary test, while the unpaired t-test was reported only as a comparator and was not used as a basis for drawing conclusions.

In the age variable, the inclusion group met the assumption of normality (p = 0.511) while the exclusion group did not (p = 0.031). According to the provision that if only one group does not meet the assumption of normality, the non-parametric test is still used for the entire comparison, the age comparison between groups is also reported with the Mann-Whitney U test.

2. Levene homogeneity test

Table 2 Levene homogeneity test results

Comparison	Statistics F	Value p	Conclusion
GCS score: inclusion group vs exclusion	1,096	0,299	Homogeneous variants
GCS score: high vs low energy mechanism	11,755	0,002	Variants are not homogeneous
Age: inclusion group vs exclusion	3,969	0,051	Homogeneous variants

The Levene test was reported as complementary and did not determine the selection of the main test, as the main determinant in this study was the normality test results. Nevertheless, the finding that the variance of GCS scores between the high-energy and low-energy mechanism groups was inhomogeneous (p = 0.002) has its own significance. The standard deviation in the high-energy group was 3.31 while in the low-energy group was only 1.05, suggesting that the high-energy mechanism produced much more varied clinical outcomes, ranging from GCS 5 to GCS 15. Because inhomogeneous variance can affect the interpretation of the Mann-Whitney test results as median differences, the results in subchapter 4.2.2 are not interpreted as median differences but rather as distribution differences in general, with the average rating as the basis for reading the direction of the difference.

The Relationship between the Mechanism of Work Accidents and the Severity of Head Injuries

Testing of the study's main hypothesis, namely the relationship between the mechanism of work accidents and the severity of head injuries, was performed in the inclusion group (n = 30). A comparison of GCS scores between the two categories of mechanisms is presented in Table 3.

Table 3 Comparison of GCS scores by mechanism of work accidents (n = 30)

1. Descriptive overview

Mechanism	n	Median (RIK)	Average ± SB	Average rating
High energy	15	13,0 (10,00–15,00)	12.33 ± 3.31	12,83
Low energy	15	15,0 (13,00–15,00)	14.33 ± 1.05	18,17

2. Test results

Test	Test statistics	Value p	Huge influence	Ranking
Mann-Whitney U	U = 72,500; Z = −1,810	0,070	r = 0.330 (moderate)	The main test, the basis of the conclusion draw
Parametric mean difference test	F = 4,980; db = 1 and 28	0,034	—	Comparisons are not used as a basis for conclusions

Note: RIK = interquartile range; SB = standard deviation. The main test was established since Chapter III based on the results of the normality test. The parametric test was reported openly as a comparison, but was not used as a basis for drawing conclusions because both assumptions were not met in this data, namely that the GCS score was not normally distributed in both groups of mechanisms (Shapiro-Wilk $p = 0.004$ and $p < 0.001$) and the variant of the two groups was inhomogeneous (Levene based on mean $F = 11.755$; $p = 0.002$). Because the shape of the distribution of the two groups is not similar, the results of the Mann-Whitney U test are interpreted as differences in general distribution read through mean ratings, not as median differences

Table 3 shows that the median GCS score in the high-energy mechanism group was 13.0 while in the low-energy group was 15.0. The average score of the high-energy group (12.83) was lower than that of the low-energy group (18.17), which means that the high-energy group tended to have a worse consciousness score. However, the difference did not reach statistical significance at the level of 0.05 ($Z = -1.810$; $p = 0.070$). The magnitude of the influence obtained was $r = 0.330$, which according to the interpretation rules is a moderate category.

A comparison of the severity of head injuries by mechanism is presented in Table 4.

Table 4. Relationship of work accident mechanism with head injury severity (n = 30)

Mechanism	Medium–heavy n (%)	Lightweight n (%)	Quantity	P* value	OR (IK 95%)
High energy	5 (33,3)	10 (66,7)	15	0,169	7,00 (0,71–69,49)
Low energy	1 (6,7)	14 (93,3)	15		1 (references)
Quantity	**6 (20,0)**	**24 (80,0)**	**30**		

*Fisher exact test. Pearson's Chi-square test yields $\chi^2 = 3.333$ ($p = 0.068$), but the smallest expected frequency is 3.00 (< 5) so the conditions for using the Chi-square test are not met and the Fisher exact test is used as the main test.

Table 4 shows that the proportion of moderate-severe head injuries in the high-energy mechanism group was 33.3%, which is five times higher than the low-energy mechanism group which was only 6.7%. The odds ratio obtained was 7.00, which means that workers with a high-energy injury mechanism were seven times more likely to suffer a moderate-severe head injury. However, the 95% confidence interval stretched from 0.71 to 69.49, i.e. past the number 1, so the relationship could not be statistically significant ($p = 0.169$).

The very wide confidence interval is a direct indication that this study lacks power, not an indication that the relationship does not exist. The calculation of the post-test test power with a proportion of 33.3% to 6.7% in a sample size of 15 subjects per group only resulted in a test power of 44.3%, well below the prevailing threshold of 80%. With the magnitude of the observed effect, it takes at least 35 subjects per group, or 70 subjects as a whole, to achieve the 80% test power. Thus, the zero hypothesis in this study is not rejected, but the direction and magnitude of the observed effects remain consistent with the research hypothesis.

Sensitivity Analysis to Categorization Mechanism

Since 15 of the 30 mechanism notes are written in general terms, the robustness of the results in subchapter 4.2.2 against categorization choices is tested through three scenarios defined in advance. The results are presented in Table 5.

Table 5 Sensitivity analysis to the categorization of the mechanism of work accidents

Categorization scenarios	n Energy height	n Energy Low	Medium–heavy proportions (high vs low)	OR	P* value
Scenario 1 (major): "fall/fall/blunt trauma" without description → low energy; "accident" → high energy	15	15	33.3% vs 6.7%	7,00	0,169
Scenario 2 (conservative): only subjects with explicit mechanisms records are analyzed	13	2	30.8% vs 0.0%	2,37†	1,000
Scenario 3 (opposite extreme): "fall/fall" without a high-energy → description	28	2	21.4% vs 0.0%	1,44†	1,000

*Fisher exact test. †Estimated by Haldane-Anscombe correction because there are cells with zero values.

Table 5 shows that in all three scenarios, the direction of the relationship remained consistent: the proportion of moderate-severe head injuries was always higher in the high-energy mechanism group. However, neither scenario resulted in a statistically meaningful relationship. The magnitude of the odds ratio shrank sharply in Scenario 2 and Scenario 3 because both scenarios resulted in a very small comparison group, i.e. only two subjects, so the estimate became very unstable.

The conclusion that can be drawn is that the results of this study are solid in terms of the direction of the relationship, but not solid in terms of the magnitude of the effect. The inconsistency stems from the quality of recording the trauma mechanism in the medical record, not from the error of analysis.

Comparison of GCS Scores between the Inclusion Group and the Exclusion Group

A comparison of GCS scores between the inclusion group and the exclusion group was aimed at identifying the role of comorbidities on the severity of the clinical presentation of head injury. The results are presented in Table 6.

Table 6 Comparison of GCS scores between the inclusion group and the exclusion group (n = 60)

Groups	n	Median (RIK)	Average ± SB	Average rating
Inclusions	30	15,0 (13,00–15,00)	13.33 ± 2.62	35,57
Exclusion	30	12,0 (9,00–15,00)	11.93 ± 2.59	25,43

Mann-Whitney U test: U = 298.0; Z = −2.330; p = 0.020; magnitude of influence r = 0.301 (medium category).

In comparison, an unpaired t test yields t = 2.084; free degrees = 58; p = 0.042; mean difference = 1.40 points.

Table 6 shows that there was a significant difference in the distribution of GCS scores between the inclusion group and the exclusion group (Z = −2.330; p = 0.020). The average score of the inclusion group of 35.57 was higher than that of the exclusion group of 25.43, which means that patients without confounding comorbidities showed a better level of consciousness. The magnitude of the influence obtained was r = 0.301, including the moderate category. The zero hypothesis was rejected and an alternative hypothesis was accepted.

The unpaired t-test reported as a comparator yielded unidirectional conclusions (p = 0.042) with an average difference of 1.40 GCS points. The directional fit between parametric and non-parametric tests reinforces the robustness of the findings, although the conclusion drawback remains based on the Mann-Whitney U test as per the provisions of Chapter III.

The Relationship of Group Status to Head Injury Severity

Table 7 Relationship of group status to head injury severity (n = 60)

Group status	Medium–heavy n (%)	Lightweight n (%)	Quantity	P* value	OR (IK 95%)
Exclusion (with comorbidities)	16 (53,3)	14 (46,7)	30	0,007	4,57 (1,45–14,39)
Inclusion (without comorbidities)	6 (20,0)	24 (80,0)	30		1 (references)
Quantity	**22 (36,7)**	**38 (63,3)**	**60**		

*Pearson Chi-square test ($\chi^2 = 7.177$; free degree = 1). The smallest expected frequency is 11.00 until the conditions for using the Pearson Chi-square test are fully met. As a cross-examination, the Fisher exact test yields p = 0.015.

Table 7 shows a significant association between the presence of comorbidities and the severity of head injury ($\chi^2 = 7.177$; p = 0.007). Patients with comorbidities were 4.57 times more likely to be categorized as a moderate-severe head injury than patients without comorbidities. The 95% confidence interval was in the range of 1.45 to 14.39 and did not exceed 1, so the association was statistically significant. The posttest power for this comparison was 77.8%, which is close to the prevalent threshold of 80%.

Relationship of Age and Gender to Head Injury Severity

Table 8 Relationship of age and sex to the severity of head injuries (n = 60)

Variable	Medium–heavy n (%)	Lightweight n (%)	χ^2	Value p	OR (IK 95%)
Gender			2,919	0,088	
Male (n = 41)	18 (43,9)	23 (56,1)			2,94 (0,83–10,39)
Female (n = 19)	4 (21,1)	15 (78,9)			1 (references)
Age group			0,431	0,512	
Intermediate adult, > 40 years (n = 24)	10 (41,7)	14 (58,3)			1,43 (0,49–4,15)
Early adulthood, ≤ 40 years (n = 36)	12 (33,3)	24 (66,7)			1 (references)

Pearson Chi-square test. The smallest expected frequency on both cross tables is 6.97 and 8.80 so that the test requirements are met.

Table 8 shows that the proportion of moderate-severe head injuries in male workers (43.9%) is more than double that of female workers (21.1%), with an Odds Ratio of 2.94. However, the association does not achieve statistical significance (p = 0.088) and the confidence interval exceeds 1. The age comparison between severity groups also does not show a meaningful relationship (p = 0.512).

The age comparison between the inclusion group and the exclusion group produced results that were right at the limit of significance (Mann-Whitney test U = 317.5; Z = −1.961; p = 0.050; r = 0.253; unpaired t test t = −1.978; degree of freedom = 58; p = 0.053). The sex distribution between the two groups was shown to be comparable ($\chi^2 = 0.077$; p = 0.781), so that sex did not play a confounding role in the comparison between groups.

Multivariate Analysis with Binary Logistic Regression

Multivariate analysis was performed to assess whether the relationship between group status and head injury severity remained meaningful after controlling for other potentially confounding variables.

The determination of variables included in the model follows two rules that have been established in Chapter III. Based on the rules of candidate selection, the variables that show a p value of less than 0.25 in bivariate analysis are group status (p = 0.007) and gender (p = 0.088), while the age group does not meet the candidate's requirements (p = 0.512). Based on the adequacy of the number of events, there were 22 subjects with moderate-severe head injuries so that the event value per variable was 22 divided by 2, which was 11.0, which met the requirement of at least ten events for each independent variable. Thus, the main model contains two independent variables, namely group status and gender. The variable input method used is the Enter method.

Before the coefficients were interpreted, all binary logistic regression assumptions were checked and declared to be met: dichotomy-shaped bound variables, no subjects were recorded more than once, there was no multicollinearity between predictors, all variables were categorically free so that the Box-Tidwell test was not required, and no influential deviations were found. The results of the analysis are presented in Table 9.

Table 9 Results of binary logistic regression analysis on the incidence of moderate–severe head injuries (n = 60)

Variable	B	Standard error (SE)	Wald	Value p	aOR	I 95%
Group status (1 = exclusion)	1,566	0,603	6,744	0,009	4,79	1,47–15,62
Gender (1 = male)	1,152	0,684	2,837	0,092	3,16	0,83–12,09
Constant	−2,240	0,724	9,571	0,002	0,11	0,03–0,44

Table 9 shows that after controlling for sex, group status remained a meaningful determinant of the incidence of moderate–severe head injuries (Wald = 6.744; p = 0.009). Patients with comorbidities were 4.79 times more likely to be categorized as moderate–severe head injuries than patients without comorbidities, with a confidence interval of 1.47 to 15.62 that did not go beyond 1. Sex was not statistically significant in the model (p = 0.092).

The assessment of the presence of confounding was not based on the p-value of the controlling variable, but rather on the magnitude of the change in the estimated main variable before and after the adjustment. The crude odds ratio for group status was 4.57, while the adjusted odds ratio was 4.79, so the change in estimate was only 4.8%. Because the change was less than 10%, sex was declared not to be a confounding factor in the relationship between group status and the severity of head injury. A similar examination of age group as an alternative controlling variable resulted in an adjusted odds ratio of 4.86 with an estimated change of 6.2%, which was also less than 10%, so that age was not declared confounder.

The feasibility of the model was checked through four tests as presented in Table 10.

Table 10 Results of the feasibility test of the binary logistics regression model

Testing	Results	Criteria	Conclusion
Omnibus Test of Model Coefficients	χ^2 = 10,493; db = 2; p = 0.005	p < 0.05	Meaningful models
Hosmer and Lemeshow Test	χ^2 = 0,003; db = 2; p = 0.998	p > 0.05	Decent models
Nagelkerke R Square	0,219 (21,9%)	Reported as is	Variance explained 21.9%

Testing	Results	Criteria	Conclusion
Classification Table	Accuracy 71.7%; sensitivity 59.1%; specificity 78.9%	Reported	Medium precision

Table 10 shows that the model is overall meaningful (p = 0.005) and feasible to use because the model's alleged value corresponds to the observation value (Hosmer and Lemeshow test p = 0.998). The Nagelkerke R Square value of 0.219 indicates that the model is able to explain 21.9% of the incidence of moderate-severe head injury variance. This value is not large and reasonable considering that the model contains only two variables, while the degree of severity of head injury is in fact also determined by the amount of trauma energy, travel time to the hospital, and the quality of pre-hospital care that is not covered in this study.

Multivariate analysis cannot be performed on the mechanism variable of work accidents. This is because the mechanism is only available in an inclusion group of 30 subjects with only 6 events of moderate-severe head injuries, so that the value of events per variable is only 6.0 and does not meet the requirement of at least ten events for each independent variable. Imposing the model on these circumstances will result in excessive coefficients and unreliable confidence intervals. Therefore, the relationship between the mechanism and severity is only reported at the bivariate level.

Subgroup Analysis Based on Exclusion Reasons

Because the exclusion group contained different reasons, the GCS score comparison was repeated in several subgroups that were each compared to the inclusion group.

Table 11 Results of subgroup analysis based on exclusion reasons

Subgroups	n	Median GCS (RIK)	P* value	Proportions Medium –Heavy	OR (IK 95%)	Value p†
Inclusion groups (referrals)	30	15,0 (13,00–15,00)	—	20,0%	1 (references)	—
a. Pure comorbidities (hypertension/diabetes mellitus)	22	13,0 (9,75–15,00)	0,063	45,5%	3,33 (0,98–11,37)	0,070
b. Hypertension only	11	14,0 (9,00–15,00)	0,579	36,4%	2,29 (0,50–10,45)	0,413
c. Diabetes mellitus only	10	12,0 (10,75–13,00)	0,012	60,0%	6,00 (1,27–28,26)	0,041
d. Exclusion without massive bleeding and referral patients	26	12,5 (10,00–15,00)	0,037	50,0%	4,00 (1,23–13,01)	0,025
e. Alcohol intoxication	4	11,0 (10,00–14,25)	0,136	75,0%	12,00 (1,05–136,80)	0,048
f. Massive bleeding	3	8,0 (8,00–9,00)	0,013	100,0%	26,38 (1,20–578,03)	0,015

*Mann-Whitney U test on the inclusion group. †Fisher exact test on the inclusion group.

Table 11 contains several findings that need to be examined. First, the subgroup that contained only pure comorbidities, namely hypertension and diabetes mellitus without including subjects with massive bleeding, referral patients, and alcohol influence, showed a tendency for lower GCS scores but did not achieve significance (p = 0.063). Second, when further analyzed, diabetes mellitus showed a meaningful association (p = 0.012; magnitude of influence r = 0.396) while hypertension did not (p = 0.579).

Third, the exclusion subgroup that had been cleared of subjects with massive bleeding and permanent referral patients showed significant differences in the inclusion group (p = 0.037; odds ratio 4.00; confidence interval 1.23–13.01). These findings are important because

they show that the difference in GCS scores between groups is not solely due to two reasons for exclusion which, by definition, are accompanied by a decrease in consciousness.

Fourth, the massive bleeding subgroup showed the heaviest outcomes with a median GCS of 8.0 and all subjects were categorized as moderate-severe. However, the number of subjects in this subgroup was only three, so the confidence interval of the Odds Ratio ranged from 1.20 to 578.03. Such a broad estimate cannot be used as a basis for drawing strong conclusions, and the same is true for the alcohol intoxication subgroup containing only four subjects. According to the provisions of Chapter III, the conclusions regarding the role of comorbidities are drawn only from the subgroup concerned and are not generalized from the exclusion group as a whole.

Summary of Hypothesis Testing Results

Table 12 Summary of the results of the test of the research hypothesis

Hypothesis	Tests used	Results	Conclusion
There is a relationship between the mechanism of work accidents and the severity of head injuries	Mann-Whitney U; Fisher exactly.	p = 0.070; p = 0.169; OR 7.00 (0.71–69.49)	H_0 accepted, Ha rejected
There was a difference in GCS scores between the inclusion group and the exclusion group	Mann-Whitney U	Z = −2.330; p = 0.020; r = 0.301	H_0 rejected, Ha accepted
There is a relationship between the presence of comorbidities and the severity of head injuries	Chi-square Pearson; Binary Logistic Regression	p = 0.007; aOR 4.79 (1.47–15.62)	H_0 rejected, Ha accepted
There is a link between sex and the severity of head injuries	Chi-square Pearson	χ^2 = 2,919; p = 0.088	H_0 accepted, Ha rejected
There is a relationship between age and the severity of head injuries	Chi-square Pearson	χ^2 = 0,431; p = 0.512	H_0 accepted, Ha rejected

The discussion in this subchapter does not repeat the data presented in subchapter 4.2, but interprets the meaning of the findings, compares them with the results of previous research that has been published as described in Chapter II, and explains its implications for science and its use.

Demographic Characteristics of Work Accident Victims

This study found that 68.3% of head injury victims due to work accidents were male with an average age of 38.32 years. This finding is in line with data from the International Labour Organization which reported the prevalence of work accidents in male workers at 108.3 per 100,000 workers, which is more than double that of female workers at 48.4 per 100,000. This finding is also in line with the research of Tandean and colleagues in North Sumatra which reported the dominance of male traumatic brain injury patients at 75.4%.

The male dominance is related to the division of roles in high-risk job sectors such as construction, industry, and plantations, which is reflected in the records of the types of work of the study subjects, including construction workers, construction workers, factory workers, garden workers, contractors, and farmers. All subjects are in the productive age range, so that head injuries due to work accidents not only have a clinical impact but also have a socioeconomic impact on families who depend on the subjects' livelihoods.

Severity Profile of Head Injuries Due to Work Accidents

The prevalence of moderate-severe head injuries in the entire study sample was 36.7%, while in the group that purely experienced trauma without confounding comorbidities it was only 20.0%. The dominance of these minor head injuries is in line with the epidemiological overview of traumatic brain injury which reports that most cases are in the mild category.

It should be noted that the dominance of mild cases causes GCS scores to accumulate at the upper limit of the instrument, which is a value of 15. This situation forms a distribution that extends strongly to the left and is the reason why non-parametric tests have been anticipated since the research design stage. Corrections to the twin numbers in the Mann-Whitney U test are important in such circumstances, because without this correction the Z value would be too small so that the significance of the results would be less detectable.

Mechanism of Work Accidents and Severity of Head Injuries

The main hypothesis of this study, that there is a meaningful relationship between the mechanism of work accidents and the severity of head injuries, is not statistically proven. The proportion of moderate-severe head injuries in high-energy mechanisms reached 33.3% compared to 6.7% in low-energy mechanisms, with an Odds Ratio of 7.00, but the p-value of 0.169 did not reach the threshold of meaning.

A meaningless p-value cannot be equated with the absence of a relationship. Three considerations support this interpretation. First, the direction of the relationship is consistent and the magnitude of the observed effect is substantial, namely the Odds Ratio of 7.00 with a magnitude of influence r = 0.330 in the Mann-Whitney test which is in the medium category. Second, the calculation of the post-test test power shows that this study only has a test power of 44.3%, so the chance of failing to detect the actual relationship reaches more than half. Third, the confidence interval that stretches from 0.71 to 69.49 indicates the uncertainty of the estimate that comes from the sample size, not the absence of effects.

Pathophysiologically, the hypothesized relationship has a strong basis. The high-energy mechanism transfers kinetic energy that exceeds the tolerance of the cranial tissue in a loading duration of less than 200 milliseconds. When the load exceeds the elasticity of the bone, a cranial fracture occurs that can press inward and cause laceration of the dura and brain to form epidural and intracerebral hematomas. At the cellular level, rapid axonal stretching in about 100 milliseconds triggers a traumatic primary axotomy that leads to diffuse axonal injury.

The pathophysiological picture is reflected in the data of this study. The subjects with the lowest GCS scores were all from high-energy mechanisms: subjects who were hit by heavy objects had GCS 5, subjects who had an accident had GCS 7 with CT-Scan findings of subdural hemorrhage and subarachnoid hemorrhage, subjects who were hit by palm fruit had GCS 8, and subjects who were hit by a vehicle at work had GCS 10 with bleeding from the nose and ears. In contrast, the group of low-energy mechanisms had the lowest GCS score of 12 with a much smaller standard deviation, which was 1.05 versus 3.31. This significant difference in the variant in the Levene test (p = 0.013) is a clinically meaningful finding: high-energy mechanisms do not always result in severe injuries, but almost all severe injuries come from high-energy mechanisms.

The biggest obstacle in testing this hypothesis comes from the quality of medical record recording. Half of the mechanism records are only general terms without information on the height of the fall or the type of vehicle involved. The sensitivity analysis in Table 4.9 shows

that the magnitude of the observed effect is very sensitive to the categorization decision. This limitation is not solely an administrative problem, but touches on the validity of clinical assessments, because trauma mechanism information is one of the bases for determining triage and suspicion of intracranial injury when the patient arrives at the Emergency Unit.

The Role of Comorbidity on the Glasgow Coma Scale

The most powerful finding in this study was the significant difference in GCS scores between the group of patients without concomitant comorbidities and the group of patients with comorbidities ($p = 0.020$; $r = 0.301$). Patients with comorbidities were 4.79 times more likely to be categorized as moderate-severe head injuries after controlling for sex.

These findings confirm the fundamental question posed in Chapter I: whether the observed decrease in consciousness on GCS scores really reflects the degree of trauma-induced brain damage, or whether it is exacerbated by pre-existing systemic pathologies. The results of this study support the second possibility. These findings are in line with the research of Salehpour and colleagues as well as several retrospective studies based on national trauma databases that reported that traumatic brain injury patients with vascular and metabolic comorbidities tended to show lower admission GCS scores as well as poorer functional outcomes.

Methodologically, these findings provide an empirical justification for the exclusion criteria that have been established in Chapter III. If the two groups were combined without sorting, some of the observed decline in GCS scores would be incorrectly attributed to the degree of mechanical trauma, even though some of them came from systemic pathologies that pre-existing the trauma event. Thus, the strict exclusion criteria in this study were proven to have a significant effect on the severity profile of the final sample.

The Role of Each Comorbidity

Subgroup analysis provided a more detailed picture of the role of each comorbidity condition. Diabetes mellitus showed a meaningful association with a decrease in GCS score ($p = 0.012$; odds ratio 6.00; confidence interval 1.27–28.26), while hypertension showed no meaningful association ($p = 0.579$).

These differences can be explained through the respective pathophysiological mechanisms. Diabetes mellitus exacerbates secondary brain injury through stress hyperglycemia that triggers lactic acidosis of brain tissue, increases cerebral edema, and accelerates the cascade of glutamate excitotoxicity. Shi and colleagues' research reported a strong inverse correlation between admission blood glucose levels and GCS scores, i.e. the higher the glucose level, the lower the measured GCS score. This mechanism works directly in the acute phase, so its effect was seen in the first GCS assessment in the Emergency Unit.

In contrast, chronic hypertension plays a role through cerebral autoregulatory disorders and vascular remodeling that increase susceptibility to intracranial hemorrhage and posttraumatic hematoma expansion. These effects are slower in nature and manifest in lesion expansion within hours to days, so they are not always reflected in the assessment of the first GCS. This explanation is consistent with the pattern of the study's findings, although the limited number of subjects in each subgroup demands caution in drawing conclusions.

The alcohol intoxication subgroup showed a proportion of moderate-severe injuries of 75.0% with a median GCS of 11.0. These findings are consistent with the understanding that

alcohol causes direct depression in the central nervous system thereby artificially lowering verbal and motor response scores, and resulting in the severity of head injuries being overassessed. However, this subgroup contains only four subjects so these findings cannot be used as a basis for drawing conclusions. It should also be noted that some large-scale studies have argued that the effect of alcohol on GCS is clinically less than one point, so the prevailing clinical consensus is caution in interpreting GCS in patients under the influence of alcohol, not ignorance of the score.

The massive bleeding subgroup showed the heaviest outcomes with all subjects categorized as moderate-severe and a median GCS of 8.0. This finding is in accordance with the nature of the condition, which by definition is accompanied by a decrease in cerebral perfusion due to hypovolemic shock, so that the decrease in consciousness is not purely caused by head injury. This is the basis for the inclusion of this condition as an exclusion criterion in Chapter III.

Clinical Implications and Implications for Occupational Safety and Health

The results of this study have three practical implications. First, at the triage level in the Emergency Unit, the assessment of GCS in patients with head injuries due to work accidents needs to be accompanied by a history of comorbidities, especially diabetes mellitus. A low GCS score in patients with diabetes mellitus may reflect a combination of trauma damage and the influence of stress hyperglycemia, so the examination of blood glucose levels at the time of admission is a useful step to interpret GCS scores appropriately.

Second, at the recording level, the incompleteness of the documentation of trauma mechanisms found in this study is a problem of service quality, not just a research problem. Records in the form of "falls" without information on height do not provide sufficient information for subsequent clinicians to assess the possibility of intracranial injury. The standardization of the format of recording trauma mechanisms in the medical records of the Emergency Unit is a corrective step that is worthy of being proposed.

Third, at the level of occupational safety and health, the finding that all severe head injuries in the inclusion group came from high-energy mechanisms in the form of falling from heights, being hit by heavy objects, and vehicle accidents, confirming that prevention efforts need to be directed specifically at these three mechanisms. The provision and supervision of the use of head protective equipment, fall prevention systems at work at heights, and vehicle traffic regulation in the work area are actions that have a direct impact on reducing the number of severe head injuries due to work.

Research Limitations

This research has a number of limitations that need to be stated openly.

1. The sample size is limited, namely 30 subjects per group, The number of moderate-severe head injury incidents in the inclusion group is only six cases, so the estimated Odds Ratio is very imprecise as seen in the width of the confidence interval. This study was also not preceded by a priori calculation of sample size, so the number of subjects was determined by the availability of medical record files in the study time range.
2. The quality of recording trauma mechanisms in medical records is not the same. Half of the records are only in the form of general terms without information on the height of the fall or the type of vehicle, so the categorization of energy transfer contains elements of

interpretation. Sensitivity analysis has been carried out to test the robustness of the results on the categorization decision.

3. The cross-sectional design does not allow the drawing of conclusions about the causal relationship. The relationships found in this study are correlated, not causal.
4. Data on the mechanism of work accidents are only available in the inclusion group, so a comparison of mechanisms between the two groups cannot be made and mechanisms cannot be included in a multivariate model.
5. This study used GCS scores at the time of the first examination in the Emergency Unit as the only marker of severity. The CT-Scan imaging findings were not recorded completely in all subjects so they could not be used as an analysis variable.
6. The research was carried out in one health service center, so the generalization of results on the worker population in North Sumatra as a whole is limited.
7. A number of subgroups in the subgroup analysis contained a very small number of subjects, namely three to four subjects, so the confidence interval produced was very wide and could not be used as a basis for drawing strong conclusions.

CONCLUSION

This study included 60 patients with occupational head injuries treated at Royal Prima General Hospital in Medan between January 2024 and December 2025. Most patients were male (n = 41; 68.3%), with a mean age of 38.32 ± 12.37 years and an age range of 19–63 years. The proportion of moderate-to-severe head injuries was 36.7% in the overall sample and 20.0% among patients without the specified potential confounding comorbidities. Occupational accident mechanisms were not significantly associated with Glasgow Coma Scale (GCS)-based injury severity (p = 0.169; odds ratio [OR] = 7.00; 95% confidence interval [CI]: 0.71–69.49); therefore, the null hypothesis was not rejected. Nevertheless, the proportion of moderate-to-severe injuries was higher among patients exposed to high-energy mechanisms (33.3%) than among those exposed to low-energy mechanisms (6.7%). The limited statistical power (44.3%) may have contributed to the nonsignificant finding. In contrast, preexisting comorbidities were significantly associated with injury severity. GCS score distributions differed significantly between patients without the specified comorbidities and those with comorbidities (p = 0.020; r = 0.301), with median scores of 15.0 and 12.0, respectively. After adjustment for sex, patients with comorbidities had 4.79 times the odds of moderate-to-severe head injury (OR = 4.79; 95% CI: 1.47–15.62; p = 0.009). The logistic regression model accounted for approximately 21.9% of the variation in the outcome, according to the reported model fit statistic. Subgroup analysis identified a significant association between diabetes mellitus and moderate-to-severe head injury (OR = 6.00; p = 0.012), whereas hypertension was not significantly associated with injury severity (p = 0.579). Neither sex (p = 0.088) nor age (p = 0.512) showed a statistically significant association with injury severity in the reported analyses.

Based on these findings, Royal Prima General Hospital in Medan should consider standardizing the documentation of occupational injury mechanisms in the emergency department (ED), including fall height, vehicle type and speed, and the characteristics of striking objects, using structured reporting categories aligned with an appropriate injury event classification system. Clinical assessments should also include documentation of preexisting

conditions, particularly diabetes mellitus and hypertension, and measurement of blood glucose levels on admission when clinically indicated. Recording relevant comorbidities alongside GCS scores may support more comprehensive interpretation of neurological findings. Occupational safety and health (OSH) personnel should prioritize preventive measures targeting high-energy injury mechanisms, particularly falls from heights, impacts from heavy objects, and workplace vehicle accidents. Recommended measures include appropriate head protection, fall protection systems, equipment safety procedures, and occupational health surveillance in high-risk sectors such as construction, manufacturing, and plantations. Future studies should recruit larger samples based on an a priori sample size calculation, preferably using prospective, multicenter designs with standardized data collection procedures. Additional clinical variables, including computed tomography (CT) findings, admission blood glucose concentrations, and blood pressure measurements, should be incorporated to improve the assessment of injury severity and potential confounding factors. Longitudinal evaluation of functional outcomes using the Glasgow Outcome Scale–Extended (GOSE) would also provide a more comprehensive understanding of recovery following occupational head injuries.

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CONFLICT OF INTEREST

The author states that there are no conflicts of interest, whether personal, commercial, or financial, that can affect the implementation and results of this study.

AUTHOR'S CONTRIBUTION

Hikmal Reza Mahendra contributes to research design, data collection and processing, system development, result analysis, and article manuscript preparation.

GENERATIVE ARTIFICIAL INTELLIGENCE USAGE STATEMENT

In the process of compiling this article, the author uses generative artificial intelligence (AI) as a tool in language refinement, writing structure, and grammar improvement. The use of AI is carried out on a limited basis and remains under the supervision of the author. All data, analysis, interpretation, and scientific substance in this article have been checked and verified by the author. The author is solely responsible for the accuracy, authenticity, and final content of the manuscript.

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