Korean J Neurotrauma. 2023 Dec;19(4):422-433
https://doi.org/10.13004/kjnt.2023.19.e61
pISSN 2234-8999·eISSN 2288-2243

KJNT

Clinical Article

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# Weekend Admission and Mortality in Patients With Traumatic Brain Injury: A Meta-analysis

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OPEN ACCESS

**Received:** Nov 20, 2023
**Revised:** Dec 4, 2023
**Accepted:** Dec 4, 2023
**Published online:** Dec 12, 2023

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**Conflict of Interest**
The authors have no financial conflicts of interest.

## ABSTRACT

**Objective:** Previous studies have reported the presence of a "weekend effect" with respect to mortality in serious emergency admissions, including cases of traumatic brain injury (TBI). However, the relationship between weekend hospitalization and TBI mortality has not been fully established. This study aimed to conduct a systematic review of available evidence and investigate differences in mortality among TBI patients between weekday and weekend admissions.
**Methods:** Electronic databases including PubMed, Cochrane Library, and Embase were used to obtain relevant articles. Mortality, as the primary outcome of interest, encompassed in-hospital or 30-day mortality. Mortality rates were compared between the 2 groups, weekend and weekday admissions. Additionally, meta-regression analysis was performed on potential confounders to verify and provide comparative results.
**Results:** A total of 7 studies involving 522,942 TBI patients were eligible for inclusion in the synthesis of the systematic review. Of these patients, 71.6% were admitted during weekdays, whereas 28.4% were hospitalized on weekends. The overall integrated mortality was 11.0% (57,286/522,942), with a mortality rate of 10.8% in the weekday group and 11.3% in the weekend group. Pooled analysis revealed no significant difference in mortality between the weekday and weekend groups (risk ratio, 0.99; 95% confidence interval, 0.90–1.09; $p$=0.78). Furthermore, the meta-regression analysis for sensitivity assessment showed no modifying effect on mortality ($p$=0.79).
**Conclusion:** This study found no difference in mortality rates between weekday and weekend admissions among TBI patients. Additional sensitivity analyses also demonstrated no significant increase in the risk of mortality in the weekend group.

**Keywords:** Traumatic brain injury; Weekend; Off-hours; Holidays; Mortality



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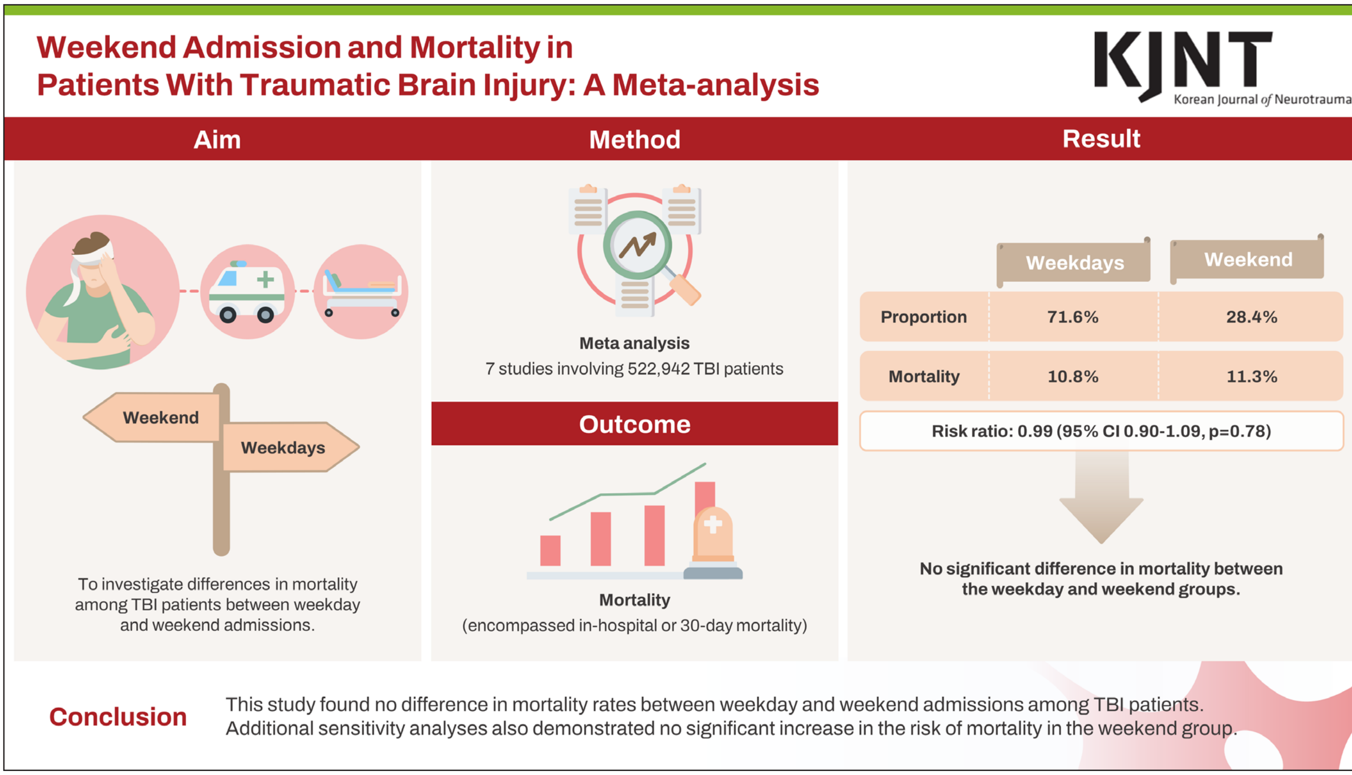
## GRAPHICAL ABSTRACT




## INTRODUCTION

Despite significant improvements in medical care for serious emergencies, traumatic brain injury (TBI) remains a major threat to life, imposing a substantial burden on healthcare systems.[4)] In the United States, TBI accounts for approximately 40% of acute injury-associated deaths and is the leading cause of mortality among younger patients.[20)] Consequently, accurately predicting mortality upon admission is crucial in effectively managing TBI patients.

In 2001, researchers initially reported the presence of the "weekend effect," indicating that patients admitted to hospitals on weekends had a higher probability of mortality compared to those admitted on weekdays.[3)] Several recent studies have further substantiated the presence of this effect, as well as the correlation between mortality rates and weekend admissions.[22,24)] Similar findings have been reported for other serious conditions such as acute myocardial infarction, ischemic stroke, and upper gastrointestinal hemorrhage.[8,29,30)]

Furthermore, studies have identified a similar "weekend effect" among TBI patients admitted to the hospital on weekends, with some suggesting that these patients experience higher in-hospital mortality rates.[1,13,26,27)] However, conflicting evidence exists, as other reports have demonstrated similar outcomes for TBI patients hospitalized on weekends compared to those admitted on weekdays.[18,25)]

Establishing a consensus on these discrepancies may help determine whether it is appropriate to prioritize the provision of neurosurgical services to TBI patients during


https://doi.org/10.13004/kjnt.2023.19.e61

weekends when staffing and facility resources are typically reduced. Therefore, this meta-analysis aimed to synthesize the available evidence regarding mortality in TBI patients hospitalized on weekends compared to weekdays.

## METHODS

Informed consent or Institutional Review Board approval was not required for this study, as it did not disclose any personally identifiable information of participants. The meta-analysis was conducted and reported in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines and the Meta-Analysis of Observational Studies in Epidemiology (MOOSE) consortium, as demonstrated in **SUPPLEMENTARY TABLE 1**.

### Data sources and searches

To ensure maximum sensitivity, a structured search strategy was developed based on the population, intervention, comparison, and outcome (PICO) format. Electronic searches were performed by 2 individual authors using databases such as PubMed, Embase, the Cochrane Central Register of Controlled Trials, and relevant websites to collect preliminary articles, including randomized controlled trials (RCTs) and retrospective observational studies.

Specific terms such as "traumatic brain injury," "weekday," "weekend," "holiday," "off-hour," "clinical outcome," and "mortality" were used (**SUPPLEMENTARY TABLE 2**), along with relevant abbreviations or synonyms, to establish the systematic search strategy. Additionally, the bibliographies of collected articles, including original articles, recent reviews, editorials, and meta-analyses, were manually reviewed to minimize the possibility of missing any eligible articles. The last literature search was conducted on November 1, 2023, with no limitations on the study design, language, or geography.

### Eligibility criteria and study selection

All studies published in any language that examined the association between the time of presentation and mortality among adult patients who presented with TBI were considered. In this study, we included articles that met the following inclusion criteria: 1) studies that compared outcomes between patients presenting on weekdays vs. weekends, and 2) studies that compared mortality outcomes, including in-hospital or 30-day mortality. These qualified articles were included in our analysis. Conversely, we excluded studies based on the following criteria: 1) studies that involved patients with injuries other than TBI; and 2) other types of articles such as abstracts, case studies, presentations, opinion or editorial letters, reviews, and expert opinions.

Abstract screening in the initial stage involved the exclusion of studies that were either non-relevant or non-original. Following this, a full-text screening process was performed by 2 authors (Jang KM and Jang JS) to evaluate eligibility. The authors independently screened abstracts and titles, identified duplicates, reviewed full-text articles, and assessed their eligibility for inclusion in the meta-analysis. Any discrepancies between the reviewers were resolved through discussion and consultation with the corresponding author to reach a consensus.

### Data extraction and quality assessment

The data extraction process involved 2 independent reviewers extracting data from the included articles. The number of patients in the weekday and weekend outcome groups was either extracted directly from the results or calculated indirectly from the data presented in the articles. A standardized template was used to extract information on the year of publication, departmental details, study design, patient demographics (including number of patients, age, sex, and comorbidities), TBI severity, baseline Glasgow Coma Scale (GCS) scores, duration of follow-up, modality for outcome measurement, and rates of surgical intervention.

In this case, the outcome of interest was mortality, which included in-hospital or 30-day mortality. Injury dates were recorded based on the day of the week the injury occurred. In this study, days were categorized into 2 groups: weekdays (Monday to Friday) and weekends (Saturday and Sunday). However, nighttime hours outside regular working hours were excluded from the eligible weekday category. Additionally, holidays were considered part of the weekend category.

To ensure consistency in the primary analysis, the risk of bias in non-RCTs and retrospective studies was assessed using the risk of bias in non-randomized studies of interventions (ROBINS-I) tool to determine the quality of the eligible studies. Articles were not excluded based on the specific thresholds mentioned in the ROBINS-I checklists.

### Data analysis

A systematic review and meta-analysis were performed for a pooled analysis of mortality outcomes across the eligible studies. The mortality rates were compared between the 2 groups by estimating the pooled rates using the random effects model and the generic inverse variance method. The results were reported as relative risk ratios (RRs) along with their corresponding 95% confidence intervals (CIs).

The original data, presented as medians with interquartile range, were converted to mean with standard deviation values. Additionally, a meta-regression analysis was conducted to validate the results and account for potential confounding factors. This analysis used the mean ages of the individual cohorts in the eligible studies to eliminate any confounding effects. Furthermore, a sensitivity analysis was performed to compare studies with relatively small vs. large volumes.

Statistical heterogeneity was assessed using the $I^2$ statistic to evaluate the degree of inconsistency among eligible studies in the meta-analysis. $I^2$ values less than 25%, 50%, and greater than 75% indicated low, moderate, and severe heterogeneity, respectively. For pooled analyses that exhibited heterogeneity greater than 50%, additional sensitivity analysis was conducted. Publication bias was examined by assessing the visual asymmetry of funnel plots and performing Egger's and Begg's tests. *p*-values below 0.05 were considered statistically significant. Statistical analysis for the systematic review was conducted using Review Manager (RevMan) Version 5.2. (Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) and STATA/SE 15.0 (Stata Corp LP, College Station, TX, USA).

## RESULTS

### Search results and quality assessment

The search of the electronic databases yielded 955 records, and after applying the inclusion criteria, 7 studies were included in the meta-analysis.[1,13,17,18,25-27] A total of 208 articles were retrieved from the systematic literature search, with 218 articles from PubMed, 255 from

Embase, and 17 from the Cochrane Central Register. After screening the titles and abstracts, 25 articles were selected for full-text review. Ultimately, only 7 articles that met the eligibility criteria were included in the study. The selection process was demonstrated to identify the studies included in the meta-analysis (**FIGURE 1**). After conducting an assessment of the quality of the studies using the ROBINS-I checklists, it was determined that a majority of the eligible studies exhibited low to moderate biases. However, one study was found to have a serious risk of bias. Detailed information on the individual judgments of the risk of bias assessment is presented in **SUPPLEMENTARY FIGURE 1** and **SUPPLEMENTARY TABLE 3**.

### Characteristics of included studies

**TABLE 1** outlines the baseline characteristics of the eligible studies, such as design, demographics, surgical intervention, and follow-up duration. For this pooled analysis, a total of 7 studies involving 522,942 patients were included to compare mortality between weekday and weekend admissions. Of these patients, 71.6% (374,566/522,942) were admitted during weekdays, whereas 28.4% (148,376/522,942) were hospitalized on weekends. Four studies enrolled individual data based on the center-level cohorts, while 3 studies used nationwide or population-based datasets. The largest population included in a study consisted of 400,426 patients in the United States. The publication year ranged from 2012 to 2023. Among the enrolled patients, 34.8% (182,024/522,942) were female. Three studies reported surgical intervention rates, with an overall rate of 58.1% (8,450/14,543). All studies examined mortality as the outcome of interest, with 5 studies reporting in-hospital mortality and the remaining 2 studies reporting 30-day mortality.

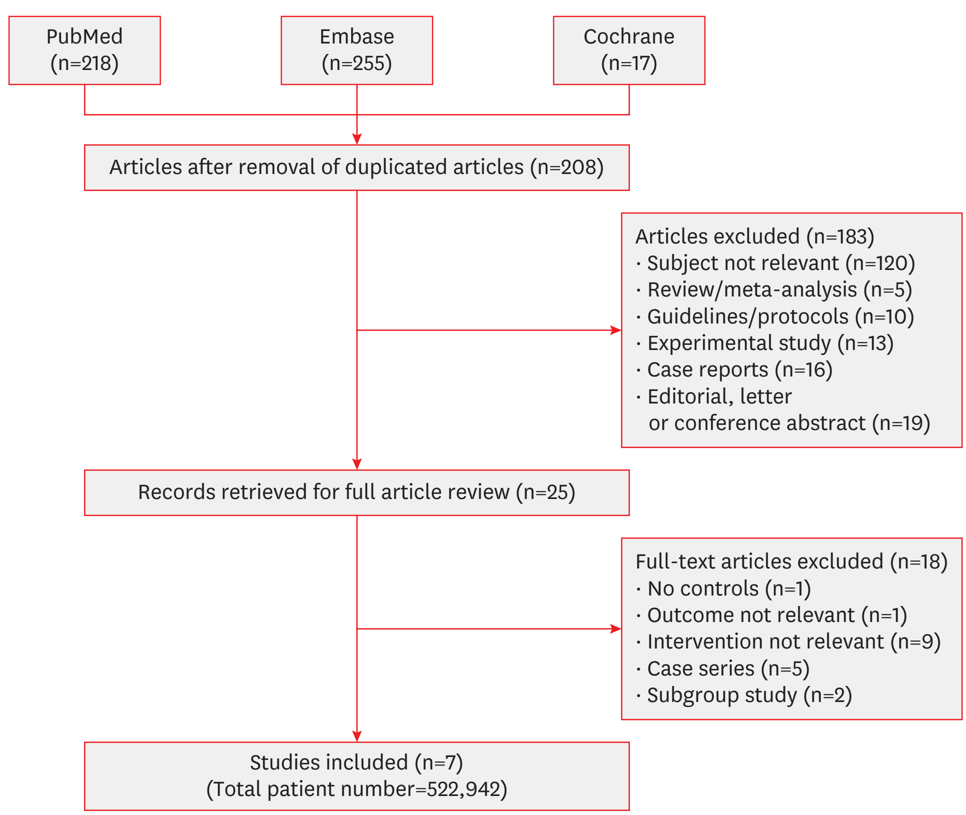



**FIGURE 1.** Flow diagram for the selection of relevant studies.

**TABLE 1.** Baseline characteristics of included studies

| Author | Design | Setting | Total | Mortality | Age (years) | Female | Surgical intervention | Endpoints | Follow-up duration |
|---|---|---|---|---|---|---|---|---|---|
| Andreassen et al.[1] (2022) | RAPD | Multi-centre | 688 | 128 (18.6) | 42.8±6.6 | 175 (25.4) | NR | Outcome, Mortality | 1 month |
| Jung et al.[13] (2023) | RO | Single-centre | 2,086 | 97 (4.7) | NR | 708 (33.9) | 506 (24.3) | Mortality | In-hospital |
| Lee et al.[17] (2008) | RAPD | Single-centre | 511 | 190 (37.2) | 47.1±20.3 | 123 (24.1) | 277 (54.2) | Mortality | In-hospital |
| Lin et al.[18] (2023) | RAPD | Single-centre | 11,946 | 363 (3.0) | 59.3±7.7 | 5,699 (47.7) | 7,667 (64.2) | Mortality | In-hospital |
| Posti et al.[25] (2021) | RAPD | Nationwide inpatient sample | 68,610 | 6,131 (8.9) | NR | 26,154 (38.1) | NR | Mortality | 1 month |
| Schneider et al.[27] (2012) | RAPD | Nationwide population study | 38,675 | 3,340 (8.6) | 78.4±6.7 | 19,560 (50.6) | NR | Mortality | In-hospital |
| Rumalla et al.[26] (2017) | RAPD | Nationwide inpatient sample | 400,426 | 47,037 (11.7) | 70.2±10.7 | 129,605 (32.4) | NR | Mortality | In-hospital |

Values are presented as number (%) or mean ± standard deviation.
RAPD: retrospective analysis from prospective database, RO: retrospective observational study, NR: not reported.

### Mortality

A total of 7 eligible articles were compared to assess mortality rates between the weekday and weekend groups. The analysis included a total of 522,942 patients, with an overall integrated mortality of 11.0% (57,286/522,942). The mortality rate was 10.8% in the weekday group and 11.3% in the weekend group. The pooled analysis, using a random effects model, revealed no statistically significant difference between the 2 groups (RR, 0.99; 95% CI, 0.90–1.09, $p$=0.78), although there was significant heterogeneity ($I^2$=87%; $p$<0.05; **FIGURE 2**). To verify the results and make comparisons, a subgroup analysis was conducted based on the study design. The subgroup analysis, which solely included studies conducted at individual centers with relatively small volumes, also did not show a significant difference in mortality rates between the weekday and weekend groups (RR, 1.01; 95% CI, 0.88–1.15; $p$=0.47). Similarly, studies using nationwide datasets with large volumes showed no significant differences in mortality rates between the 2 groups (RR, 0.98; 95% CI, 0.87–1.10; $p$=0.24) (**FIGURE 3**). Meta-regression analysis did not reveal any modifying effect of the mean age on the primary outcomes ($p$=0.79) (**FIGURE 4**).

Funnel plots for mortality, as illustrated in **SUPPLEMENTARY FIGURE 2**, showed no obvious asymmetry. Furthermore, the Egger's and Begg's tests did not reveal any significant differences.

| Study | Weekday Events | Weekday Total | Weekend Events | Weekend Total | Weight | Risk Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| Andreassen 2022 | 90 | 457 | 38 | 231 | 5.9% | 1.20 [0.85, 1.69] |
| Jung 2023 | 33 | 809 | 64 | 1277 | 4.5% | 0.81 [0.54, 1.23] |
| Lee 2008 | 95 | 263 | 95 | 248 | 10.4% | 0.94 [0.75, 1.18] |
| Lin 2023 | 252 | 8143 | 111 | 3803 | 10.7% | 1.06 [0.85, 1.32] |
| Posti 2021 | 4214 | 45562 | 1917 | 23048 | 22.8% | 1.11 [1.06, 1.17] |
| Schneider 2012 | 2418 | 28738 | 922 | 9937 | 21.5% | 0.91 [0.84, 0.97] |
| Rumalla 2017 | 33418 | 290594 | 13619 | 109832 | 24.2% | 0.93 [0.91, 0.94] |
| **Total (95% CI)** | | **374566** | | **148376** | **100.0%** | **0.99 [0.90, 1.09]** |
| Total events | 40520 | | 16766 | | | |

Heterogeneity: Tau² = 0.01; Chi² = 46.69, df = 6 (P < 0.00001); I² = 87%
Test for overall effect: Z = 0.27 (P = 0.78)

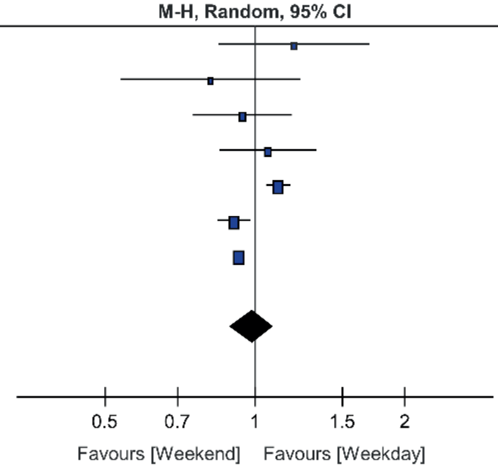



**FIGURE 2.** Forest plot of mortality rates in patients with traumatic brain injury who were admitted to hospital in the weekend compared to the weekday period.
M-H: Mantel-Haenszel, CI: confidence interval.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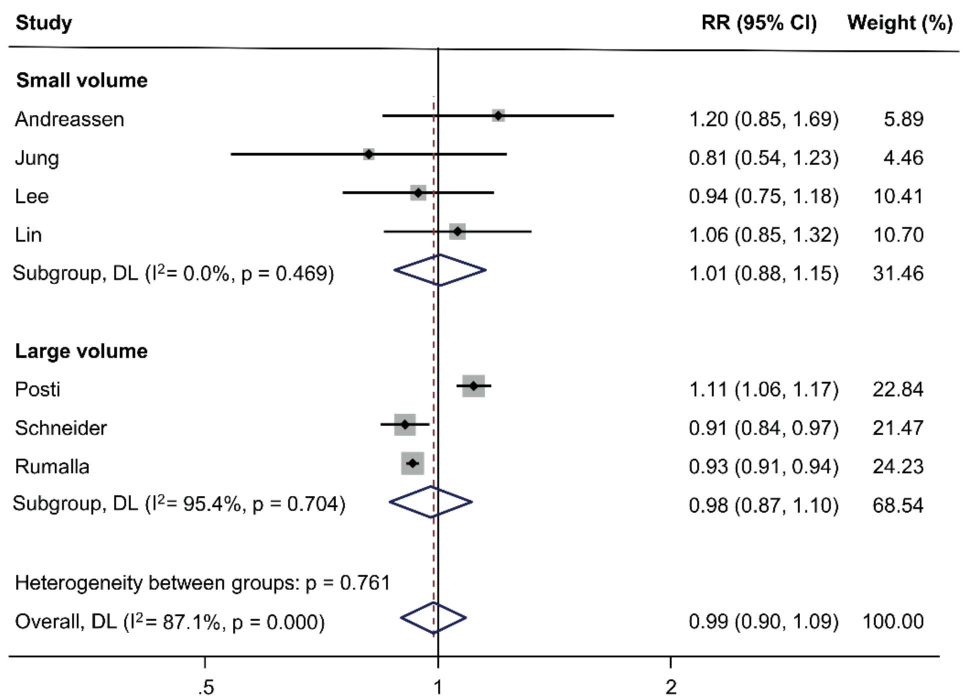


**FIGURE 3.** Forest plot of mortality rates in patients with traumatic brain injury who were admitted to hospital in the weekend compared to the weekday period on small volume and large volume studies.
RR: risk ratio, CI: confidence interval, DL: DerSimonian and Laird method.

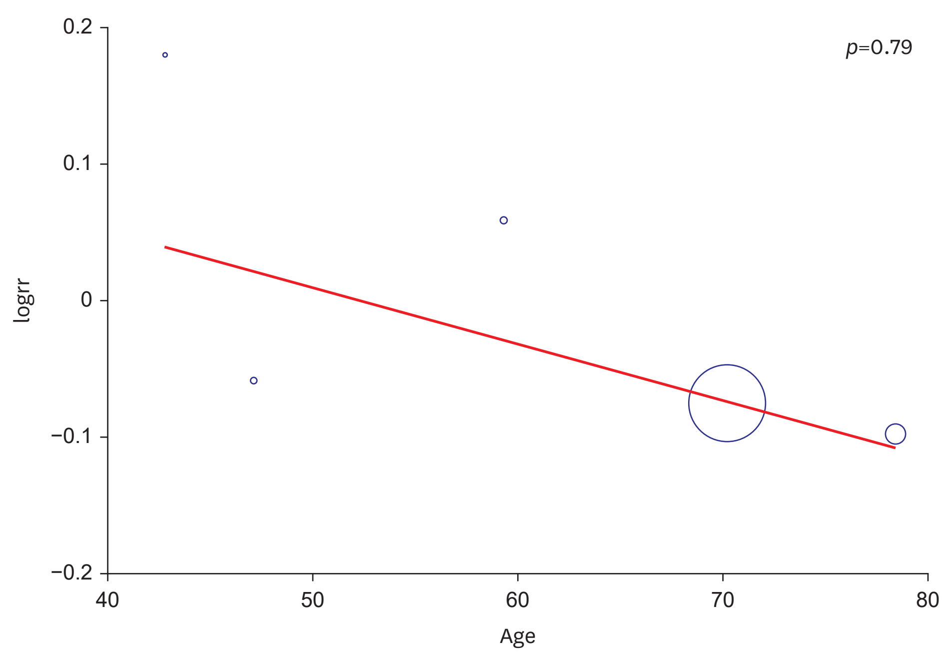


**FIGURE 4.** Meta-regression analysis of the mean age on the mortality rates in traumatic brain injury.


https://doi.org/10.13004/kjnt.2023.19.e61

## DISCUSSION

The present systematic review aimed to evaluate the available evidence regarding the relationship between mortality and the timing of hospital arrival (weekday vs. weekend). This study-level meta-analysis included 7 studies comprising 522,942 participants. The findings did not reveal any significant difference in mortality between the weekday and weekend groups. Subgroup analysis also indicated that there was no difference in mortality rates based on the study design. Furthermore, age did not have a confounding effect on mortality, according to the meta-regression analysis.

Several recent studies have demonstrated the presence of the "weekend effect" or the association between mortality and patient admission during holidays.[24,31] Of these, one of the largest studies, conducted by Bell and Redelmeier[3] included over 3 million participants and compared mortality rates among acute care admissions from emergency departments in Ontario, Canada, between 1988 and 1997. The study included a total of 3,789,917 admissions, encompassing a variety of medical conditions including ruptured abdominal aortic aneurysm (5,454 admissions), acute epiglottitis (1,139), and pulmonary embolism (11,686), and 3 control diseases, myocardial infarction (160,220), intracerebral hemorrhage (10,987), and acute hip fracture (59,670). The results of this study showed higher mortality rates among patients admitted during the weekends compared to weekdays. Additionally, various studies have indicated that patients admitted to the emergency department at night or during weekends tend to have worse clinical outcomes than those admitted during daytime or weekdays. This phenomenon, commonly referred to as the "weekend effect" or "off-hour effect," refers to the variation in clinical outcomes between patients admitted on weekdays vs. weekends, or between daytime and nighttime admissions.[12,32,33] In contrast, when examining the weekend effect in greater detail by differentiating it based on specific diseases, its existence remains highly debated. Previous reports have shown that the effect of off-hour emergency department arrival on hospital mortality varies for different diseases. For instance, the effect was not significant for cervical trauma and stroke, while it was significant for acute kidney injury, atrial fibrillation, and abdominal aortic aneurysm.[6,9,10,23]

Despite the significant burden and mortality rate associated with TBI, the consensus on the "weekend effect" in relation to TBI has not been fully established. Some articles have reported a significant relationship between mortality and admission on weekends. For instance, Posti et al.[25] conducted a study using a nationwide database for Finland and found a significant increase in TBI-related mortality among patients admitted on holidays and weekends. Similarly, Little et al.[19] analyzed data on patients from a trauma database in London and identified high mortality rates among those admitted on weekends. Notably, the only published meta-analysis on this topic found significant difference in mortality rates between weekday and weekend admissions.[34]

In contrast, recent studies have failed to identify any difference in mortality between patients admitted with TBI on weekends compared to weekdays. Andreassen et al.[1] reported that although a greater number of patients were admitted on weekends, the mortality rate did not differ from that for weekday admissions. Moreover, several studies have indicated no evidence of a "weekend effect" for TBI patients.[13,26,27]

Our findings align with the latter results. The pooled analysis showed that there was no significant difference in mortality rates between patients admitted with TBI on weekends


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compared to weekdays. To the best of our knowledge, this meta-analysis is the largest study to date and contributes toward establishing a consensus on the insignificance of the "weekend effect" on mortality among TBI patients. This finding implies that the reduced availability of resources and delays in diagnostic or therapeutic procedures during weekends may not have a significant impact on the mortality rate of TBI patients.

Although several studies suggest poorer clinical outcomes for patients admitted on weekends, the causes of the "off-hours effect" remain unclear. One possible explanation is a reduction in the number of personnel, the availability of substitute temporary staff, and a decrease in the availability of intervention resources.[5,15] Furthermore, the cognitive status of surgeons, necessary for making appropriate clinical decisions, is likely to be affected by fatigue during off-hours.[28] Previous studies have suggested that such resource limitations may result in higher mortality.[12,13] However, Lin et al.[18] argued that level I/II trauma centers are sufficiently well-resourced to provide trauma services of equal quality at all hours. The studies included in our meta-analysis also consisted of studies conducted at level I/II trauma centers. Additionally, we specifically selected studies conducted at academic institutions rather than non-academic hospitals, which potentially diluted the weekend effect.[11]

Another factor to consider is the management of severe cerebral hemorrhage, such as subarachnoid hemorrhage, where highly trained surgeons and medical and nursing staff are required to deliver meticulous and high-quality patient care.[7] It is less likely that senior surgeon supervision for managing subarachnoid haemorrhage is available on weekends when senior staff is generally limited.[14] Conversely, surgery for TBI is likely to have a relatively lesser stiff learning curve and requires relatively less precise manipulation. Therefore, it is assumed this factor contributes to the insignificant gap in mortality rates between weekdays and weekends.

Finally, certain traumatic events, such as mild to moderate TBI, may not require immediate interventions. Patients with minimal injuries are often kept overnight. Delaying surgery on weekends and holidays may not significantly impact mortality rates for non-life-threatening injuries. The widely recognized principle of 'time is brain,' in the field of ischemic stroke may not be a crucial factor in TBI.[29] Rather, it is more likely that the severity of the injury, rather than the timing, determines the outcome of TBI.[16] Various studies have reported that, in multivariate analysis considering the time interval, the severity of the injury itself is more strongly related to the outcome than the delay in treatment.[2,16,21] These findings provide evidence supporting our results, indicating the lack of a significant relationship between mortality and the "weekend effect" in TBI patients.

Indeed, several heterogeneities are associated with the limitations of our study. First, the heterogeneity in the severity of TBI among the included studies should be acknowledged as a limitation. The presence of heterogeneity in the selection of eligible studies may introduce confounding factors that need to be considered when interpreting the results. Meanwhile, the results of investigating relationship between weekend admission and TBI severity have been reported in some studies. First, Little et al.[19] analyzed the Trauma database and reported that there was no significant difference in admission GCS scores between weekdays and weekend hospitalizations among TBI patients. On the other hand, Tiruneh et al.[31] investigated the Israeli National Trauma Registry and, although not GCS, reported that the overall injury severity score was statistically significantly higher in weekend group. In conclusion, there has not been a complete consensus or evidence yet that the TBI severity of


https://doi.org/10.13004/kjnt.2023.19.e61

weekend hospitalizations is significantly higher, so whether severity acts as a confounder of the "weekend effect" needs to be investigated through further studies in the future. Second, some heterogeneity may arise owing to the inability to distinguish outcomes based on specific TBI diagnoses. Given the differences in outcomes associated with specific diagnoses, it is essential to consider the heterogeneity in TBI diagnoses. The heterogeneity in surgical interventions is also regarded as a potential confounding factor that should be addressed in future research. To obtain more accurate results, further studies with controlled and homogeneous samples that account for these confounders are needed.

## CONCLUSION

In this study, no difference in mortality was observed between weekday and weekend admissions among TBI patients. We found no evidence of an increased risk of mortality associated with the "weekend effect." Additional sensitivity analyses revealed no significant increase in the risk of mortality in the weekend group.

## SUPPLEMENTARY MATERIALS

### SUPPLEMENTARY TABLE 1

Checklist of items to include when reporting a systematic review or meta-analysis (PRISMA guideline)

Click here to view

### SUPPLEMENTARY TABLE 2

Search strategy in accordance with the population, intervention, comparison and outcome (PICO) format

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### SUPPLEMENTARY TABLE 3

The risk of bias assessment for non-randomized controlled trial using risk of bias in non-randomized studies of interventions (ROBINS-I) tool

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### SUPPLEMENTARY FIGURE 1

"Traffic light" plot of the domain-level judgements for each individual result using risk of bias in non-randomized studies of interventions (ROBINS-I) tool.

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### SUPPLEMENTARY FIGURE 2

Funnel plots for evaluating publication bias for mortality rates.

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