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Original Article

**Autopsy findings and identification process in severely burned bodies:
A four-year retrospective case series****^{ID}Abdullah Benna Sarin¹, ^{ID}Toygun Anil Ozesen², ^{ID}Caner Ileri¹, ^{ID}Mehmet Ali Yildiz³**¹The Council of Forensic Medicine, Hatay Group Chairmanship, Hatay, Türkiye²The Council of Forensic Medicine, Ankara Group Chairmanship, Ankara, Türkiye³Alanya Branch Office, Council of Forensic Medicine, Antalya, Türkiye

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**Abstract****Aim:** The identification and forensic evaluation of severely burned bodies can be challenging because fire may destroy both anatomical features and critical evidence. This study aimed to evaluate the autopsy findings, vitality indicators, toxicological results, and identification-related challenges in fire-related deaths.**Materials and Methods:** This retrospective case series included nine fire-related deaths autopsied at the Council of Forensic Medicine, Van Branch, between 2018 and 2021. Autopsy reports and forensic investigation records were reviewed for demographic characteristics, incident circumstances, burn severity, vitality indicators, toxicological findings, cause and manner of death, and the feasibility of visual identification.**Results:** Six victims were male and three were female, with all female victims being children. Six cases (66.7%) involved foreign nationals, and all deaths were classified as accidental. Soot was detected in the airways of all cases. carboxyhemoglobin (COHb) levels could be measured in three pediatric cases and ranged from 32% to 43%. Carbon monoxide poisoning was reported as the cause of death in two cases and as a contributing factor together with burn injuries in one case. Six adult victims had advanced fourth-degree burns, making visual identification impossible. Alcohol, illicit drugs, and fire accelerants were not detected in any case.**Conclusion:** Vitality indicators, particularly airway soot and COHb levels, should be evaluated together in fire-related deaths. DNA analysis and dental examination are particularly important when visual identification is impossible. Heat-related artifacts should also be carefully distinguished from true traumatic injuries.**Keywords:** Fire-related deaths, carbonization, victim identification, carbon monoxide poisoning, forensic autopsy, vitality markers**INTRODUCTION**

Fire-related deaths constitute a significant public health concern and represent a common category of forensic cases. It is estimated that approximately 10% of such cases result from intentionally set fires. Therefore, all fire-related fatalities should be treated as suspicious, and in bodies recovered from fire scenes, the possibility that the manner of death may be suicide or homicide must be thoroughly investigated [1]. Although fire-related deaths are not uncommon in forensic practice, their investigation is considered among the most challenging due to the potential destruction of both the body and critical crime scene evidence by the fire [2].

Another frequent challenge in fire-related fatalities is determining whether the individual was already deceased prior to the onset of the fire. For instance, an elderly individual may collapse and die due to a fatal cardiac arrhythmia, after which a toppled heater could ignite a fire. Conversely, setting fire to a residence after placing a body inside to conceal a homicide is also a well-documented method. In light of such scenarios, meticulous evaluation of vitality indicators is essential in every fire-related death [1].

The most important indicators of vitality in burned bodies, demonstrating that the individual was alive during the fire, are the presence of soot deposition in the airways and elevated levels

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of carboxyhemoglobin (COHb) in the blood [3]. In assessing whether a person was alive at the time of exposure to flames in a fire environment, a COHb level exceeding 10% is generally considered a significant finding [4]. However, if COHb levels are low and the body is found in a burned state, the possibility that the individual was alive at the time of the fire cannot be entirely excluded. Conditions such as laryngeal spasm, exposure to toxic gases produced in the fire environment (e.g., cyanide, nitrogen oxides, phosgene), or injuries resulting from an explosion may lead to death during the fire despite low blood CO levels [4].

Deaths related to fires most commonly occur as a direct consequence of burn injuries. However, carbon monoxide poisoning or inhalation of other toxic gases may also constitute the cause of death [5]. Particularly in residential fires, when household items burn at a low intensity for a period of time, dense smoke accumulates in the environment, and victims may lose their lives due to the toxic effects of smoke rather than direct exposure to flames. In such cases, although carbon monoxide poisoning is the most common cause of death, burning synthetic materials may also release other lethal gases, such as cyanide [6].

In more intense and prolonged fires, advanced carbonization develops in the bodies; findings may range from the classical flexion posture known as the “pugilistic attitude” to completely charred bones and ash remains. In mass fire disasters involving multiple fatalities, where remains may become commingled, both the identification of burned bodies and the determination of the cause of death become extremely challenging [7]. In such situations, since soft tissues are often completely destroyed, preserved skeletal structures—particularly teeth—play a critical role in identification [8]. Furthermore, certain heat-related artifacts observed in severely burned bodies (e.g., heat fractures or heat hematomas within the skull) may mimic true traumatic lesions, posing a significant challenge in forensic evaluation [2].

The aim of this study was to retrospectively evaluate the demographic characteristics, autopsy and toxicological findings, vitality indicators, and identification-related findings of fire-related fatalities examined at the Council of Forensic Medicine, Van Branch, between 2018 and 2021.

MATERIAL AND METHOD

This study included all cases (n = 9) autopsied at the Council of Forensic Medicine – Van Branch between January 1, 2018 and December 31, 2021, with a history of being recovered from a fire scene. Autopsy reports and forensic investigation files were reviewed to obtain demographic data (age, sex, nationality), incident characteristics (type of fire, scene location, date), external examination findings (degree of burns, extent of carbonization, clothing and personal belongings, integrity of the body), and internal/toxicological findings (organ burns, presence of soot in the airways, COHb levels, alcohol and drug analyses).

Identification-related data, including the feasibility of visual identification and the use of DNA comparison, dental records,

personal belongings, or other investigative evidence, were also obtained from the autopsy reports and forensic investigation files.

All data were recorded in Microsoft Excel and subjected to descriptive analysis. The findings are presented in tables and percentages with respect to the victims’ sociodemographic characteristics and forensic examination results.

The study was conducted in accordance with the principles of the Declaration of Helsinki. Institutional approval was obtained from the Education and Scientific Research Commission of the Council of Forensic Medicine, Ministry of Justice of the Republic of Türkiye (approval date: February 22, 2023; approval no.: 21589509/2023/114). All data were anonymized, and identifying information was kept confidential.

RESULTS

Of the nine cases included in the study, six were male and three were female; all female cases were in the pediatric age group (one was a 13-month-old infant, and the other two were aged 3 and 5 years). The ages of the male cases could not be determined; however, all were adults and recorded as migrant workers. A total of 66.7% of the cases (n = 6) were of foreign nationality (presumably undocumented immigrants from abroad), while the remaining three cases were Turkish citizens.

In all nine cases examined, the manner of death was assessed as accidental; no evidence of homicide or suicide was identified in the forensic investigation records. Regarding the scene, three cases died in indoor residential fires, whereas the remaining six cases lost their lives in outdoor fire settings (workplaces, vehicles, or open areas). The demographic distribution of the cases and scene-related data are summarized in Table 1.

Table 1. Sociodemographic characteristics and scene of incident (n = 9)

Characteristic	No of cases (%)
Sex – Male	6 (66.7%)
Sex – Female	3 (33.3%)
Age Group – Child (<18 years)	3 (33.3%) – (5 y, 3 y, 13 mo)
Age Group – Adult	6 (66.7%) – (ages unspecified)
Nationality – Foreign	6 (66.7%)
Nationality – Turkish	3 (33.3%)
Scene of Incident – Home/Residence	3 (33.3%)
Scene of Incident – Other (Non-residential)	6 (66.7%)
Manner of Death – Accident	9 (100%)

Key findings from the autopsy and toxicological analyses of the cases are presented in Table 2. Soot was detected in the airways of all nine cases. In six cases, there were advanced burns (fourth-degree) with complete carbonization of the body, whereas in three cases (the pediatric cases), burns were limited to second- and third-degree. In six of the adult cases, visual identification of the bodies was not possible due to complete destruction of the face and distinguishing features by fire. In contrast, the pediatric

cases demonstrated largely preserved body integrity, with facial and anatomical features partially recognizable.

Table 2. Identification and autopsy findings

Finding / observation	No. of cases (%)
Soot in respiratory tract	9 (100%)
COHb measured	3 (33.3%)
High COHb (> 10%)	3 (33.3%)
COHb not measured (sample unavailable)	6 (66.7%)
Visual identification possible by appearance	3 (33.3%)
Visual identification impossible (extensive burns)	6 (66.7%)
Advanced burn (4th-degree)	6 (66.7%)
Partial burn (2nd–3rd degree)	3 (33.3%)
Pugilistic posture (heat flexion)	5 (55.6%)
Body cavity opening (heat artifact)	3 (33.3%)
Limb loss (heat artifact)	4 (44.4%)
Heat-induced bone fractures	6 (66.7%)
Accelerant detected (fire accelerant)	0
Toxicology positive for alcohol/drugs	0
Cause of death – burn complications	6 (66.7%)
Cause of death – CO poisoning	2 (22.2%)
Cause of death – combined burns + CO	1 (11.1%)

Depending on the severity of the burns, the typical “pugilistic attitude” (heat-induced flexion posture) was observed in five cases. Due to exposure to high temperatures, spontaneous opening of body cavities (such as the skull or thorax) was identified in three cases, while in four cases, extremities (such as arms or legs) were found to be detached or missing. In six cases, multiple heat-related fractures were observed in the skeletal system. Notably, in the skeletal examination of two cases (severely burned adult cases), extensive fragmentation and fractures of multiple long bones due to advanced burning were identified (e.g., bilateral fractures of the right forearm, multiple fractures in the wrists and lower leg bones). According to the forensic investigation records, the identities of the severely burned adult cases were established primarily through comparison with familial DNA samples, supported by personal belongings recovered from the scene.

No evidence of gunshot wounds or sharp/penetrating injuries was detected in any of the cases (pre-autopsy radiographic screening examinations were also negative).

COHb levels could be measured in only three of the nine cases (the pediatric cases), from whom blood samples were obtained. In these three cases, COHb levels were determined to be 40%, 43%, and 32%, respectively. In the remaining six cases, CO levels could not be assessed due to the inability to obtain blood and internal organ samples as a result of advanced burning.

As the cause of death, six cases were attributed to burn injuries at the level of carbonization and burn-related complications (such as burn shock and fluid–electrolyte imbalance), whereas

in two pediatric cases, the cause of death was reported as carbon monoxide poisoning. In one case (a 13-month-old infant), both burn injuries and carbon monoxide inhalation contributed to death.

No alcohol, illicit drugs, or other toxic substances were detected in any of the cases. Additionally, forensic laboratory analyses did not identify any fire accelerant residues (e.g., gasoline, thinner) in any of the cases.

DISCUSSION

This study presents the characteristics and identification process of nine fatal cases recovered from fire scenes over a four-year period in Van province. Although the number of cases is limited, evaluation of the findings in light of the literature reveals several parallels and noteworthy points. All nine deaths included in the present series were classified as accidental.

Although all deaths in our series were classified as accidental, this finding should be interpreted cautiously because of the small sample size. In a five-year Istanbul series, 98 of 133 fire-related deaths (73.7%) were accidental, 12 (9.0%) were homicidal, and 23 (17.2%) were undetermined, with no suicidal cases [1]. Another Turkish autopsy series classified 119 of 158 deaths (75.3%) as accidental, 9 (5.7%) as homicidal, 5 (3.2%) as suicidal, and 25 (15.8%) as undetermined [9]. Similarly, an Italian study reported 25 accidental, eight suicidal, three homicidal, and three undetermined deaths among 39 cases [10]. Therefore, the absence of homicide or suicide in the present series likely reflects the limited sample size and regional case characteristics rather than a general pattern of fire-related deaths.

In all nine cases in our study, the presence of vitality indicators (soot in the airways and/or carbon monoxide inhalation) is noteworthy. This finding demonstrates that the victims were alive at the time of the fire. In particular, COHb levels exceeding 30% in the three pediatric cases suggest that carbon monoxide poisoning played a primary role in death. According to the literature, the detection of COHb levels above 10% is considered a strong indicator that the individual was alive during the fire [3,4]. Carbon monoxide intoxication was reported to contribute to death, either alone or in combination with burns or smoke inhalation, in 74 of 158 cases (46.8%) in a Turkish autopsy series [9]. In the present series, carbon monoxide poisoning had a direct or contributory role in three of nine cases (33.3%). However, COHb levels could not be measured in six cases because suitable biological samples were unavailable due to advanced carbonization; therefore, a direct numerical comparison should be interpreted cautiously.

Nevertheless, low COHb levels may be measured in some fire-related deaths; in such cases, the presence of soot in the airways and other forensic findings must be evaluated collectively. For example, in our series, CO levels could not be determined in any of the adult migrant cases; however, the presence of soot in the trachea and bronchi indicated that these individuals were breathing in the fire environment. As reported by Byard, even

an apparently “straightforward” fire-related death should be examined in depth, as the absence of soot in the body or low COHb levels may indicate that death occurred prior to the fire and may substantially alter the course of the forensic investigation [2]. The presence of at least one vitality indicator (and in most cases, both) in all of our cases constitutes an important finding confirming that death was fire-related.

The identification process represents one of the most challenging aspects of forensic practice, particularly in severely burned bodies. Destruction of both superficial and deep tissues due to burning eliminates the possibility of using fingerprints, facial recognition, and distinguishing features such as scars or marks for identification [7]. Carbonization of the facial tissues and thermocoagulation-related restriction of mouth opening may significantly complicate the collection and interpretation of dental findings in severely burned bodies. In a series of severely burned victims, final identification was achieved using DNA findings [11]. An examination of skeletal samples from 23 fire victims demonstrated an inverse relationship between thermal exposure and both DNA yield and STR profile quality. Nevertheless, optimized extraction methods produced full or partial STR profiles from severely burned remains [12]. These findings support the combined use of dental examination and DNA analysis, particularly from preserved teeth and skeletal tissues, when visual identification is impossible.

In such circumstances, dental records and DNA analyses constitute the most reliable methods for identification [8]. Teeth provide highly valuable data in the identification of fire victims, as they are more resistant to high temperatures than most skeletal structures [8]. If dental records (e.g., panoramic radiographs, treatment records) are available, identification can be achieved through forensic odontology examinations. However, this method is often not applicable in foreign nationals or undocumented individuals.

In such cases, DNA analysis becomes the most effective option. Well-preserved skeletal tissues (e.g., long bone shafts or dental pulp) are the most suitable sources for obtaining DNA from severely burned bodies. The literature reports that even in the 2009 Victoria bushfire disaster, identification of burned victims was successfully achieved through DNA analysis [7]. On the other hand, in remains exposed to extremely high temperatures for prolonged periods, DNA retrieval may become impossible; in such situations, the identification process must rely entirely on case-specific evidence (e.g., jewelry, prostheses, clothing fragments, personal belongings).

There are also certain challenges in the interpretation of autopsy findings in fire-related cases. Findings known as heat artifacts represent changes induced in the body by the burning process and must be distinguished from true traumatic lesions. For example, in bodies exposed to high temperatures, false accumulations of blood such as dural or epidural collections (heat hematomas) may occur due to increased intracranial pressure; these should be differentiated from true intracranial hemorrhage [2].

Similarly, cracking or fracturing of bones due to sudden exposure to heat is a common finding, and such heat-induced fractures were identified in many cases in our study. These fractures are postmortem artifacts and cannot always be easily distinguished macroscopically from fractures resulting from traumatic impact. Although several cases in our series exhibited multiple fractures in the extremities, forensic investigation and radiological evaluation concluded that all of these findings were postmortem changes related to the fire. An experimental study involving 30 human forearm bones found that several morphological features overlapped between mechanically induced and heat-induced fractures. Nevertheless, differences in fracture-surface morphology and discoloration patterns could assist differentiation [13]. These findings support the cautious interpretation of the multiple fractures observed in our cases and demonstrate that macroscopic findings should be evaluated together with radiological and, when necessary, microscopic examinations.

Our study has several important limitations. The number of cases is extremely small and reflects only the regional data of a single forensic medicine unit. Therefore, our findings are not generalizable, and statistical inference could not be performed. However, detailed evaluation of each case indicates that the findings are consistent with the literature and include representative examples, particularly with regard to vitality during the fire and identification processes. In the future, larger multicenter studies may allow for a more comprehensive analysis of the common characteristics and differences among fire-related deaths across the country.

CONCLUSION

In forensic practice, encountering bodies recovered from fire scenes is not uncommon. Successful investigation and identification of such cases require a meticulous and multidisciplinary approach. In particular, the scene investigation must be conducted thoroughly; the origin of the fire, factors contributing to its spread, and any potentially suspicious circumstances should be carefully examined.

Pre-autopsy radiological screening of the body may facilitate the detection of foreign objects such as bullets or knife fragments, thereby revealing possible evidence of homicide. During the autopsy, appropriate sampling must be performed to identify vitality indicators in burned bodies (e.g., soot and COHb), and toxicological analyses should be conducted in all cases. Determination of COHb levels, in particular, should be specifically requested in addition to routine toxicological examinations, and blood samples should be properly collected and submitted to the laboratory.

In the external examination, all personal characteristics of the body (e.g., clothing fragments, jewelry, prostheses, scars, implants) should be carefully documented and photographed. In severely burned and unrecognizable cases, biological samples (especially suitable bone or dental specimens for DNA analysis) must be

collected for identification purposes. Dental examination should be performed, dental features recorded, and consultation with a forensic odontologist should be requested when appropriate.

Furthermore, detailed pathological and radiological evaluations are recommended to distinguish heat-related artifacts from true traumatic lesions in suspicious findings. In conclusion, in forensic cases involving fire-related deaths, adopting an integrated approach encompassing scene investigation, autopsy, and laboratory analyses, evaluating all findings holistically, and supporting the identification process with modern forensic techniques are of paramount importance for the administration of justice.

Conflict of Interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

The authors declare that they have received no financial support for the study.

Ethical Approval

The study was conducted in accordance with the principles of the Declaration of Helsinki. Institutional approval was obtained from the Education and Scientific Research Commission of the Council of Forensic Medicine, Ministry of Justice of the Republic of Türkiye (approval date: February 22, 2023; approval no.: 21589509/2023/114).

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Original Article

**Evaluation of forensic reports in cases
under 18 years of age between 2023 and 2025****Erkal Gumusboga, Mesut Yilmaz, Abdulkerim Yayla, Ceren Pektekin, Nisanur Gecici***İnönü University, Faculty of Medicine, Department of Forensic Medicine, Malatya, Türkiye*

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**Abstract****Aim:** The aim of this study is to retrospectively describe the demographic characteristics, types of incidents, injury patterns, and forensic evaluation outcomes of pediatric forensic cases assessed at a single center between 2023 and 2025.**Materials and Methods:** In this retrospective descriptive study, finalized forensic reports issued for individuals under 18 years of age at a single center between 2023 and 2025 were reviewed retrospectively. The cases were evaluated in terms of age, sex, type of incident, injury site, presence of bone fracture, life-threatening condition, and forensic evaluation outcomes. The data were analyzed using descriptive statistics.**Results:** A total of 179 pediatric forensic cases were included in the study. Of the cases, 66.5% were male and 33.5% were female. Traffic accidents were identified as the most common type of incident. Injuries were most frequently observed in the head and neck region, and the number of cases was found to increase during the summer months.**Conclusion:** This study reveals that traffic accidents are the most common type of incident in pediatric forensic cases and that injuries predominantly occur in the head and neck region. The study findings indicate a possible association between male sex and increased risk. It also indicates that the frequency of cases increases during the summer months.**Keywords:** Child, forensic report, traffic accident, injury**INTRODUCTION**

According to the laws of our country, individuals who have not reached the age of 18 are classified as children and, except for cases in which they are legally recognized as adults under certain conditions, they are legally evaluated within this scope. As awareness of children's rights has increased globally, the importance of these rights has been recognized; therefore, the Convention on the Rights of the Child, adopted by the United Nations General Assembly on November 20, 1989, was published in the Official Gazette in our country on January 27, 1995, and entered into force [1]. According to the provisions of the Convention, the state should aim to protect children against all forms of maltreatment that may come from caregivers, prevent

child abuse, and organize social programs for the rehabilitation of children exposed to such treatment [2].

Currently, human rights are protected under Article 17 of the Constitution of our country, which states that everyone has the right to life and the right to protect and develop their material and spiritual existence, and clearly emphasizes that, except in certain legally defined circumstances, the bodily integrity of the individual is inviolable [3]. Therefore, any incident constituting an assault on bodily integrity is considered a forensic case, and any injury that may contain an element of crime, even in the absence of intent, falls within the scope of a forensic case and must be reported. Although forensic reports may be prepared by physicians as a form of notification to judicial authorities when

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encountering a situation that may involve suspicion of a crime, detailed forensic reports are generally prepared upon request by judicial authorities [4].

Accidents are among the leading causes of injury in children; however, it should also be taken into consideration that injuries resulting from violence and penetrating or sharp object trauma are quite common. Among accidents, home accidents, falls, impacts/collisions, and traffic accidents can be listed [5]. Although accidents may primarily be considered non-forensic in nature, forensic case notification is made due to possibilities such as the incident having occurred differently from the reported history or having resulted from negligence, and judicial authorities evaluate whether the incident contains any criminal elements.

The aim of our study was to retrospectively examine the finalized forensic reports issued by the Department of Forensic Medicine at İnönü University Turgut Özal Medical Center for individuals under 18 years of age at the time of the incident between 2023 and 2025, in terms of incident types and injury characteristics.

MATERIALS AND METHODS

Our study was retrospective and descriptive in nature and was conducted at the Department of Forensic Medicine, İnönü University Faculty of Medicine. Of the 206 cases under 18 years of age who were referred between January 1, 2023, and July 31, 2025, a total of 179 were included in the study. Cases for which a finalized report could not be issued, preliminary reports, and cases for which additional information was requested were excluded from the study. In addition, repeated admissions were not included, as they were merged with previous reports.

In our evaluation, the Guideline for the Forensic Medical Evaluation of Injury Crimes Defined in the Turkish Penal Code was used as the basis in order to establish a common opinion regarding the characteristics of injuries that may affect the judicial process and the decisions rendered, as defined under Turkish law as “injuries minor enough to be treated by simple medical intervention, injuries resulting in a life-threatening condition, the effect of fracture or dislocation on vital functions, permanent weakening/loss of the function of one of the senses or organs, and permanent scar on the face” [6]. The cases were evaluated in terms of age, sex, injury site, whether the injury was minor enough to be treated by simple medical intervention, the presence of bone fracture or dislocation, the effect of fracture or dislocation on vital functions, permanent weakening or loss of sensory or organ function, and the presence of a permanent scar on the face.

Injuries considered minor enough to be treated by simple medical intervention can be described as injuries that are easy to manage and generally do not require further examination or treatment, such as abrasions limited to the skin, ecchymoses, and small lacerations. Injuries resulting in a life-threatening condition include skull fractures, intracranial hemorrhage, brain tissue destruction, and injuries to any internal organ or major vessel.

Fractures are classified according to their effect on vital functions as mild (1), moderate (2–3), and severe (4–5–6). When multiple fractures occur in the same bone, the highest fracture score among them is taken into consideration. In cases of fractures in more than one bone, the square of each fracture score is calculated and summed, and the square root of this sum is taken and rounded to the nearest whole number to determine the total fracture score.

A permanent facial scar is defined as a scar that is clearly noticeable at first glance from conversational distance (1–2 meters). Organ-specific approaches are followed in determining permanent weakening or loss of the function of sensory organs or other organs.

Ages were classified according to developmental stages, aiming to achieve as balanced groups as possible and to reflect periods in which personality characteristics change. The age groups were determined as 0–2, 3–6, 7–11, 12–14, and 15–17 years, representing early childhood, preschool period, school age, early adolescence, and late adolescence, respectively [7].

Ethical approval for the study was obtained from the Non-Interventional Clinical Research Ethics Committee of İnönü University Faculty of Medicine on October 14, 2025, with decision number 2025/8332. Statistical analyses were performed using IBM SPSS Statistics 22 software. Percentage distributions were calculated in the analyses.

Due to the length of the names of the criteria evaluated in our study, certain abbreviations will be used. The term “minor enough to be treated by simple medical intervention” will be abbreviated as simple medical intervention, while the term “not minor enough to be treated by simple medical intervention” will be abbreviated as non-simple medical intervention. The term “injuries resulting in a life-threatening condition” will be abbreviated as life-threatening condition, whereas “Injuries not resulting in a life-threatening condition” will be abbreviated as non-life-threatening condition.

RESULTS

Of the 179 cases examined, 60 (33.5%) were female and 119 (66.5%) were male.

It was found that 171 cases (95.5%) were citizens of the Republic of Türkiye.

It was observed that male admissions were higher in all age groups; however, from the age of 3 onward, this difference was approximately twofold (Figure 1).

When grouped according to seasons, injuries were found to occur most frequently during the summer season (Figure 2).

When the injuries were examined in terms of whether they caused bone fractures, bone fractures were identified in 54 cases (30.2%). When fractures were classified according to their effect on vital functions as mild (1), moderate (2–3), and severe (4–5–6), it was found that 14 cases (7.8%) had fractures that severely affected vital functions (grade 6) (Figure 3).

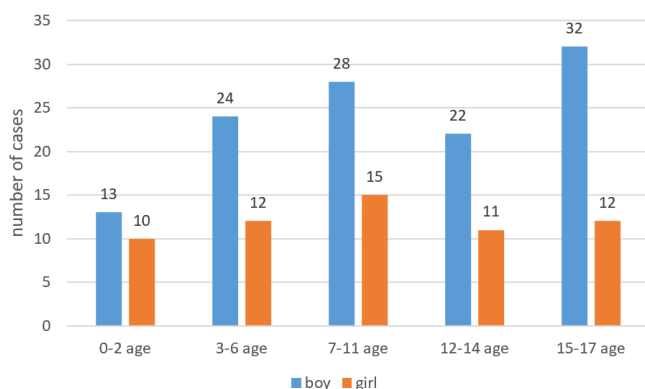


Figure 1. Distribution of cases by age group and sex

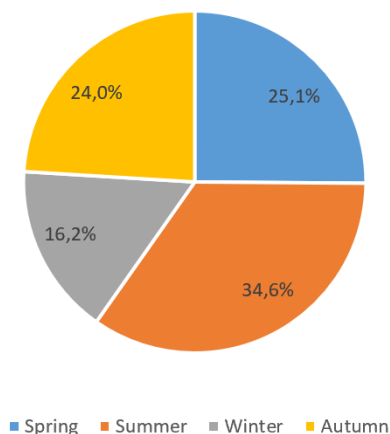


Figure 2. Seasonal distribution of cases

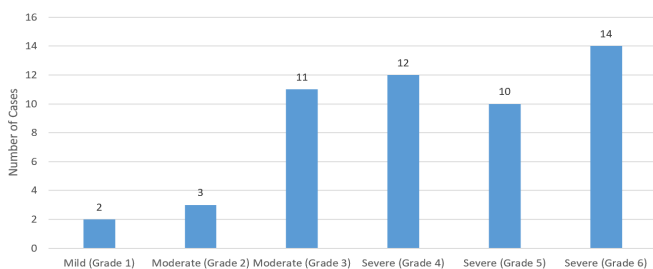


Figure 3. Distribution of cases according to bone fracture severity grades

It was found that in 79 cases (44.1%), the injuries were not minor enough to be treated by simple medical intervention, and in 49 cases (27.4%), the injuries caused a life-threatening condition.

Among the 64 cases (35.7%) with injuries within the boundaries of the face who were evaluated for permanent facial scarring, it was found that the injuries in 2 cases (1.1%) were considered to constitute a permanent facial scar or permanent facial disfigurement, while the injuries in 7 cases (3.9%) were determined not to constitute a permanent facial scar or permanent facial disfigurement. In 54 cases (25.1%), the healing period had not yet been completed, and in 1 case (0.55%), evaluation could not be performed because the patient did not return for follow-up.

When evaluated in terms of permanent weakening or loss of sensory or organ functions, it was found that there was no

weakening or loss in 121 cases (67.6%), weakening was identified in 3 cases (1.7%), and evaluation could not be performed in 55 cases (30.7%) due to the healing period not being completed or failure to attend follow-up.

When the types of incidents were examined, traffic accidents constituted the largest proportion with 92 cases (51.4%), followed by falls with 21 cases (11.7%) and assault with 19 cases (10.6%).

It was found that 38 cases (21.2%) were concluded following physical examination, whereas 141 cases (78.8%) were finalized based on the available documents.

In both sexes, the head and neck region was the most frequently injured area, and bone fractures were also most commonly observed in this region. This was followed by lower extremity injuries (Table 1).

It was observed that the most common mechanism of injury was, by a clear margin, traffic accidents, and accordingly, injuries causing life-threatening conditions were most frequently associated with traffic accidents among the cases in this study. Non life-threatening condition was identified in cases of suicide attempt, assault, poisoning, or firearm injury (Table 2).

Although injuries most frequently occurred in the head and neck region, the correlation between injuries in this region and life-threatening conditions was found to be relatively low. In contrast, it was determined that nearly half of the cases involving pelvic and thoracic injuries were associated with life-threatening conditions (Table 3).

In traffic accidents, the most commonly affected body region was the head and neck (27.8%), followed by the lower extremities (18.4%) and cases with no detected injury (16.5%). Head and neck injuries were also the most frequent in assault cases (38.9%), while they were particularly prominent in fall-related cases (64.0%). In burn cases, injuries were more homogeneously distributed across body regions, whereas in poisoning cases, injuries were predominantly concentrated in the abdominal region (83.3%). In sharp object injuries, upper extremity injuries were the most common (45.5%), while thoracic injuries were the most prominent in firearm injuries (33.3%). Abdominal injuries were identified in all suicide attempt cases (100%). Overall, the head and neck region stood out as the most frequently affected anatomical area across many trauma mechanisms (Table 4).

Table 1. Distribution of bone fracture regions among cases

Fracture region	n	%
Skull	23	42.6
Face-neck	13	24.1
Thorax	6	11.1
Pelvis	6	11.1
Spine	6	11.1
Upper extremity	11	20.4
Lower extremity	22	40.7

Table 2. Distribution of injuries requiring simple medical intervention according to mechanism of injury

Mechanism of injury	Simple medical intervention n (%)	Non simple medical intervention n (%)	Total n (%)
Traffic accident	51 (55.4)	41 (44.6)	92 (100)
Fall	9 (42.9)	12 (57.1)	21 (100)
Assault	15 (78.9)	4 (21.1)	19 (100)
Penetrating injury	5 (45.5)	6 (54.5)	11 (100)
Poisoning	10 (100.0)	0 (0.0)	10 (100)
Burn	4 (50.0)	4 (50.0)	8 (100)
Natural disaster	2 (25.0)	6 (75.0)	8 (100)
Firearm injury	0 (0.0)	4 (100.0)	4 (100)
Home accident	2 (66.7)	1 (33.3)	3 (100)
Suicide attempt	2 (100.0)	0 (0.0)	2 (100)
Other	0 (0.0)	1 (100.0)	1 (100)
Total	100 (55.9)	79 (44.1)	179 (100)

Table 3. Life-threatening condition status by injury region

Injury region	Life-threatening n (%)	Non-life-threatening n (%)	Total n(%)
Head-neck	33 (38.4)	53 (61.6)	86(100)
Lower extremity	18 (39.1)	28 (60.9)	46(100)
Upper extremity	15 (37.5)	25 (62.5)	40(100)
Thorax	22 (57.9)	16 (42.1)	38(100)
No injury	0 (0.0)	31 (100.0)	31(100)
Abdomen	9 (34.6)	17 (65.4)	26(100)
Pelvis	10 (52.6)	9 (47.4)	19(100)
Lumbar	2 (40.0)	3 (60.0)	5(100)
Total*	108 (37.1)	183 (62.9)	291(100)

* The total number of cases was 179; however, since some cases involved more than one injury site, the injury locations were classified separately, and a total of 291 injury sites were identified

Table 4. Relationship between mechanism of injury and injury regions

Type of injury/injury region	Head-neck	Thorax	Abdomen	Lumbar	Pelvis	Lower extremity	Upper extremity	No injury	Total
Traffic accident	44 (27.8%)	21 (13.3%)	10 (6.3%)	1 (0.6%)	10 (6.3%)	29 (18.4%)	17 (10.8%)	26 (16.5%)	158
Assault	14 (38.9%)	5 (13.9%)	1 (2.8%)	2 (5.6%)	2 (5.6%)	5 (13.9%)	5 (13.9%)	2 (5.6%)	36
Fall	16 (64.0%)	1 (4.0%)	0	0	0	3 (12.0%)	4 (16.0%)	1 (4.0%)	25
Burn	4 (20.0%)	4 (20.0%)	1 (5.0%)	0	3 (15.0%)	4 (20.0%)	4 (20.0%)	0	20
Poisoning	0	2 (16.7%)	10 (83.3%)	0	0	0	0	0	12
Home accident	1 (50.0%)	1 (50.0%)	0	0	0	0	0	0	2
Natural disaster	1 (9.1%)	0	0	0	2 (18.2%)	4 (36.4%)	2 (18.2%)	2 (18.2%)	11
Firearm injury	1 (16.7%)	2 (33.3%)	0	0	1 (16.7%)	1 (16.7%)	1 (16.7%)	0	6
Sharp or penetrating object injury	0	2 (18.2%)	1 (9.1%)	2 (18.2%)	1 (9.1%)	0	5 (45.5%)	0	11
Suicide attempt	0	0	2 (100%)	0	0	0	0	0	2

* The total number of cases was lower than that presented in the table; however, as some cases involved multiple injury sites, the injury locations were classified separately

DISCUSSION

In this study, finalized forensic reports issued for individuals under 18 years of age at Turgut Özal Medical Center between 2023 and 2025 were retrospectively reviewed. It was determined that 66.5% of the cases were male and 33.5% were female. The higher proportion of male children being involved in forensic cases was found to be consistent with the 75.2% rate reported in the study conducted in Samsun by Karaarslan et al. and with the predominance of males in the retrospective review conducted in Erzurum by Baydemir Kılınç et al. [8,9]. According to the findings obtained, the marked increase in the difference in case numbers from the age of 3 onward, when personality traits begin to become more apparent, suggests that male sex may be associated with involvement in forensic incidents [5]. This situation may be explained by boys spending more time outdoors and having a relatively greater tendency toward culturally and psychologically risky behaviors.

It was determined that injuries occurred most frequently during the summer season (34.6%). This finding is consistent with the study conducted by Göçeoğlu et al., which showed that young cases in Muğla were exposed to trauma more frequently during the summer months [10]. The increased opportunities for children to spend time outdoors during the summer and the fact that most cases consisted of traffic accidents support this result.

The most common type of incident in this study was traffic accidents (51.4%). This finding is consistent with the study conducted by Baydemir Kılınç et al., which reported that approximately half of pediatric trauma cases were due to traffic accidents [9]. In the study conducted by Karaarslan et al. in Samsun, intentional injury ranked first, whereas the predominance of traffic accidents in this study suggests that there may be regional differences and indicates the need for further multicenter research on this issue [8]. Falls (11.7%) and assault (10.6%) ranked second and third, respectively, while in the study conducted by Özdeş et al. in Kastamonu, assault and sexually related incidents were reported to be more common than traffic accidents [11]. These findings indicate that preventive measures and stricter supervision targeting preventable causes such as traffic accidents and falls should be increased in the region where the study was conducted. Measures aimed at preventing traffic accidents may include increasing the use of child car seats, stricter speed enforcement in school zones, and enhanced traffic safety education.

The head and neck region was identified as the most common site of injury (48.3%). This finding is consistent with the results of the pediatric trauma study conducted by Baydemir Kılınç et al. at Atatürk University, in which head-neck and extremity injuries were prominent [9]. On the other hand, the low frequency of pelvic injuries and the fact that nearly half of these cases were associated with life-threatening injuries suggest that the pelvis, due to its relatively small volume and surface area, is a comparatively protected region in trauma and is less likely to be injured in low-energy trauma [12]. The rate of bone fractures was

30.2%, and severe functional impairment was identified in 7.8% of cases. This rate is consistent with the rates of serious fractures reported in the literature on pediatric trauma [13,14]. According to the data presented in Figure 3, the relatively low frequency of grade 1 and grade 2 fractures may be attributed to the fact that most cases consisted of injuries such as traffic accidents and falls, which cause generalized bodily trauma, and such trauma is less likely to result in fractures limited to small bones. The fact that fracture grading was performed in accordance with the national forensic medicine guideline based on the Turkish Penal Code also supports methodological consistency.

A life-threatening condition was present in 27.4% of cases and was most frequently associated with traffic accidents. This once again highlights the importance of traffic accidents in forensic trauma during childhood. The rate of permanent facial scarring was found to be low at 1.1%; however, 30.2% of cases could not be evaluated because the healing period had not been completed or because the patients did not attend follow-up. This finding is similar to the study by Karaarslan et al., in which a significant proportion of reports were concluded based on file review rather than direct examination [8].

The highest frequency of injuries was observed in the 15–17 age group, and an increase in causes of injury other than traffic accidents was noted in this group. In this age range, the most common cause of injury following traffic accidents was assault, followed by sharp or penetrating object injuries; it was noteworthy that the rates of exposure to intentional injury increased. The 7–11 age group ranked second in frequency, with only one case fewer. This finding is similar to studies analyzing pediatric forensic cases presenting to the emergency department, which have shown that school-age children are more frequently exposed to trauma [15].

The main limitations of this study include its retrospective design; the fact that 78.8% of the cases were concluded based on file review; the limited variety and number of cases referred due to the location of our center; the possibility that being a tertiary referral center may have affected case characteristics; and the high proportion of cases that could not be evaluated for parameters such as permanent facial scarring and sensory or organ function.

CONCLUSION

This study demonstrates that pediatric forensic cases evaluated at a single center were predominantly associated with traffic accidents, that male cases were represented at a higher rate, and that the number of cases increased markedly during the summer months. Although head and neck injuries were the most common injury pattern, thoracic and pelvic injuries were found to correlate with cases assessed as life-threatening.

The findings obtained highlight the importance of strategies and preventive measures aimed at reducing traffic accidents, particularly for children and adolescents in high-risk age groups. In addition, it is emphasized that injury patterns with the potential

to result in severe outcomes should be carefully considered during the forensic evaluation process.

Considering the retrospective design and single-center nature of this study, there is a need for multicenter and prospective studies with greater case diversity that may contribute to the development of preventive policies and forensic practices in the pediatric population.

Conflict of Interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

The authors declare that they have received no financial support for the study.

Ethical Approval

Ethical approval for the study was obtained from the Non-Interventional Clinical Research Ethics Committee of İnönü University Faculty of Medicine on October 14, 2025, with decision number 2025/8332.

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Original Article

**Online information seeking on disability and injury in Türkiye:
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**Abstract**

Aim: The aim of this study is to compare online information search behaviors regarding the concepts of "disability" and "injury" in Türkiye, using Google Trends data, in terms of time, geography, and content.

Materials and Methods: In this retrospective and descriptive infodemiological study, relative search volume (RSV) data of web searches conducted in Türkiye in the "Health" category between July 1, 2024, and July 1, 2025, were examined.

Results: The weekly mean RSV value for the term "injury" was found to be 58.49 ± 19.40 , and the value for the term "disability" was 8.09 ± 18.62 . Reportable search interest was detected for injury in 51 weeks and 22 provinces, and for disability in 10 weeks and 9 provinces. Relative interest in injury was found to be higher in all nine provinces where both terms could be measured. When the relevant queries were examined, it was seen that disability searches focused on basic concepts, regulations, and patient rights; while injury searches focused on clinical and legal issues such as blunt and penetrating injury and the Turkish Penal Code.

Conclusions: The results show that the online information search regarding injury is more persistent and widespread than that regarding disability; and that there is a need for understandable, reliable, up-to-date, and accessible digital health content in both areas.

Keywords: Google trends, disability, injury, Türkiye

INTRODUCTION

Injuries are a significant component of the burden of disease, resulting in temporary or permanent loss of function in addition to mortality. The Global Burden of Disease 2019 study reported that injuries from traffic accidents, interpersonal violence, and self-harm are among the leading causes of loss of healthy life years, especially in young individuals. It was also noted that the number of years spent with disability is increasing within the burden of disease [1]. Disability is not merely a diagnosis or physical impairment; it is a multidimensional condition that should be evaluated in the interaction of the individual's functional level with personal and environmental factors [2].

Issues such as the nature and severity of the injury, causality, loss of function, life-threatening condition, disability, and access to rights directly intersect clinical care with forensic evaluation. The World Health Organization also defines equal access to health information and services for individuals with disabilities as a priority area for health systems [3].

With the widespread use of digital tools in all areas today, the internet has become one of the primary sources of information for individuals to understand symptoms related to their health status, make decisions about seeking healthcare, learn about diagnostic and treatment options, and prepare for consultations with clinicians [4,5]. Analysis of data from the Household

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Information Technology Use Survey in Türkiye has shown that online information search behavior in the health field varies according to age, gender, education, region of residence, and frequency of internet use [6]. Therefore, digital search engine data is a complementary data source for investigating which health concepts the community searches for information about, when, and where. Within the infodemiology approach, Google Trends, while not directly measuring disease incidence or individual information needs, can provide an anonymous and aggregated indicator of temporal and geographical interest [7-11].

Although injury and disability are clinically and legally linked, comparing community-level information searches for these two concepts within the same time, geography, and health category settings can reveal apparent information needs, legislative and rights-based questions, and regional differences. Such a comparison can help clinicians, forensic experts, and healthcare institutions identify their priorities for understandable, reliable, and accessible digital content. The aim of this study is to compare the relative interest in the search terms “disability” and “injury” in the Google Trends Health category in Türkiye between July 1, 2024, and July 1, 2025, at the temporal and provincial levels; and to assess information needs within the scope of forensic sciences by identifying related and rising queries.

MATERIALS AND METHODS

Study Design

This study was designed as a retrospective and comparative infodemiology study examining online information search behavior related to disability and injury in Türkiye. Infodemiology is defined as an approach that examines the distribution and determinants of information produced and searched in electronic environments at the community level [7]. The use of Google Trends data in health research allows for the examination of temporal relevance, geographical differences, and information search needs, but requires the explicit reporting of search term, geography, time range, category, search type, and access date for reproducibility [8-11]. In reporting the study, the applicable provisions of the STROBE principles for observational research were considered for this type of study [12].

Data Collection

Data was obtained from the publicly available Google Trends interface and outputs exported to Excel files. Search parameters were defined as “Türkiye” for the geographic region, “Health” for the category, July 1, 2024-July 1, 2025 for the date range, and “Web Search” for the search type. The terms “Disability” and “Injury” were used as Turkish search terms instead of subject headings, and comparative interest over time, interest by sub-region, and related queries outputs were recorded [13].

Google Trends provides search volumes as relative search volume (RSV), not absolute search count. Each data point is scaled on a range of 0-100 after being compared to the total Google searches in the same location and time period; 100 may indicate

the highest relative interest in the selected comparison, 50 may indicate interest at half that level, and 0 may indicate a search volume too low to be reported, not a true absence of searches [8,13]. Therefore, RSV values were not interpreted as the number of people or the absolute number of searches. Empty cells in the regional single-term tables were not populated with zeros; provinces were considered to have no value generated by Google Trends due to insufficient search volume. In the comparative regional breakdown, the relative shares of the two terms for each province were evaluated as percentages. Related queries were examined as “top queries” showing the most frequently searched phrases along with the term examined in the same search session, and “rising queries” showing the phrases showing the greatest increase compared to the previous equivalent period [14]. In top queries, 100 represented the highest relative query interest. Rising queries were reported as a percentage increase. The entry “what is blunt injury”, which appeared twice in the raw injury file, was deduplicated and the same value was retained.

Ethical Aspects: The study used publicly available secondary data from Google Trends, anonymized, categorized, and aggregated [13]. No individual identification information, IP address, demographic characteristics, medical records, or biological material was collected; no human participants were contacted or interfered with. Therefore, the study was not a human participant study and did not require ethical committee approval or informed consent. Data were reported only at the community and provincial level; no inferences were made regarding the attribution of low-volume searches to individuals.

Statistical Analysis: Analyses were performed using the SPSS 21.0 software package. Weekly RSV values were summarized as mean $\pm$ standard deviation, median (first-third quartile), minimum-maximum, and number of weeks with values greater than zero. Regional and relevant query data were defined by frequency, percentage, rank, and RSV values; provinces left blank due to insufficient volume were excluded from regional comparisons.

RESULTS

Search interest over time

The evaluated time series covered 53 weeks of observation (Figure 1). The mean weekly RSV for the term “disability” was 8.09 ± 18.62 , while the mean for the term “injury” was 58.49 ± 19.40 (Table 1). RSV greater than zero was recorded for disability in only 10 weeks (18.9%), and for injury in 51 weeks (96.2%). The zero values here may indicate interest below Google Trends’ reporting threshold, not absolute absence of searches.

The highest week for disability search interest was November 3, 2024 (RSV = 89), followed by high weeks October 27, 2024 (RSV = 60) and April 20, 2025 (RSV = 44). Injury search interest peaked in the week of May 25, 2025 (RSV = 100); This was followed by November 10, 2024 (RSV = 95) and November 17, 2024 (RSV = 88).

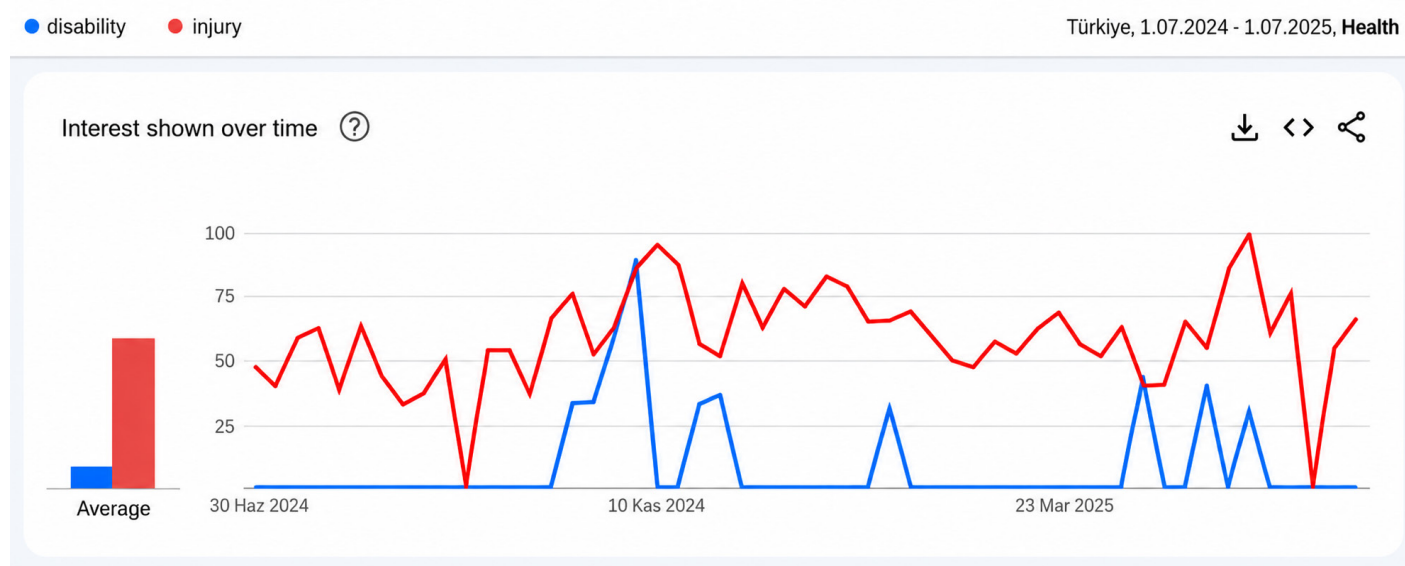


Figure 1. Interest in search terms over time

Table 1. Descriptive characteristics of weekly relative search volumes of search terms

Search term	n	Mean $\pm$ SD	Median (Q1-Q3)	Min-max	RSV > 0 weeks, n (%)
Disability	53	8.09 $\pm$ 18.62	0 (0-0)	0-89	10 (18.9)
Injury	53	58.49 $\pm$ 19.40	59 (50-68)	0-100	51 (96.2)

RSV: relative search volume, SD: standard deviation, Q1-Q3: first and third quartiles

Search interest by sub-regions

Reportable RSV at the provincial level was available in 22 provinces (27.2%) for injury and in 9 provinces (11.1%) for disability. The highest regional interest in disability searches was seen in Diyarbakır (RSV = 100), followed by Manisa (85) and Gaziantep (70). In injury searches, Aydın (RSV = 100), Erzurum (75) and Adana (59) were the top-ranked provinces (Table 2).

In the comparative regional analysis, measurable data was

available for both terms in 9 provinces, data was generated only for the injury term in 13 provinces, and there was no reportable data for either term in 59 provinces. In all nine provinces where both terms were measurable, the relative share of injury within the province was higher than that of disability. The injury rate was lowest in Diyarbakır at 52% and highest in İzmir at 83% (Table 3). The provinces with only injury data were Adana, Aydın, Denizli, Erzurum, Hatay, Kayseri, Konya, Mersin, Muğla, Sakarya, Samsun, Şanlıurfa, and Tekirdağ.

Table 2. Provinces with the highest search interest by sub-region

No	Disability – province	RSV	Injury – province	RSV
1	Diyarbakır	100	Aydın	100
2	Manisa	85	Erzurum	75
3	Gaziantep	70	Adana	59
4	Bursa	65	Şanlıurfa	55
5	Ankara	50	Mersin	53
6	Kocaeli	40	Gaziantep	51
7	Antalya	30	Denizli	51
8	İstanbul	25	Hatay	51
9	İzmir	20	Konya	51
10	—	—	Tekirdağ	50

*The outputs were normalized on a scale of 0-100.

Table 3. Comparative search rates in provinces where measurable data is available for both search terms

Province	Disability rate	Injury rate
Diyarbakır	48%	52%
Manisa	40%	60%
Bursa	38%	62%
Gaziantep	33%	67%
Ankara	30%	70%
Kocaeli	29%	71%
Antalya	23%	77%
İstanbul	23%	77%
İzmir	17%	83%

Related queries

The highest-ranking query related to disability was “what is disability” (index = 100), followed by “what is handicap” (index = 43) and “types of disability” (index = 16). The inclusion of queries such as “Regulation on Disability Assessment for Adults” (index = 8) and “what are patient rights” (6) in the list showed that the information search covered not only definitional content but also legislation and rights-based topics (Table 4).

The most frequent query related to injury was “blunt injury” (index = 100); This was followed by “what is blunt injury” (index = 54). In rising queries, after deduplication of duplicate records, a 60% increase was observed for “what is blunt injury” and a 50% increase for “what is blunt”. In particular, queries related to “Turkish Penal Code injury” and the disability assessment regulation revealed that the information needs examined included forensic-medical and legislative components.

Table 4. Most searched queries related to search terms

No	Disability-related query	Index	Injury-related query	Index
1	What is disability?	100	Blunt injury	100
2	What is a handicap?	43	What is a blunt injury?	54
3	Types of disability	16	What is blunt?	53
4	Classes of disability	12	TPC injury	40
5	Regulation on Disability Assessment for Adults	8	Penetrating injury	32
6	What are patient rights?	6	What is a penetrating injury?	18
7	—	—	Causes of injury	5
8	—	—	What does blunt mean?	5

Index = 100 indicates the most frequently searched query in the same session for the relevant term; other values show relative interest accordingly; TPC: Turkish Penal Code

DISCUSSION

The most important finding of this study is that in 49 out of 53 weeks examined in Türkiye, the relative search interest for the term “injury” was significantly higher compared to the term “disability”. Furthermore, while reportable data was obtained for the term “injury” in 51 weeks and 22 provinces, data was only available for the term “disability” in 10 weeks and 9 provinces. These findings suggest that, at the general search term level, information searches related to injury show greater temporal continuity and a wider geographical distribution compared to disability. However, considering that RSV is a normalized indicator of interest and does not reflect the absolute number of searches or the frequency of events, this result cannot be interpreted as meaning that the incidence or social burden of injury is greater than that of disability [8-11,13].

One possible explanation for the high and sustained search interest in injury is that injury can create a need for quick information about symptom interpretation, urgency, treatment, and legal consequences following a sudden event. It has been reported that online health information searches can influence individuals’ decision to seek healthcare, their preparation for the interview, and their communication with the clinician [4,5]. In this study, the prominence of queries such as “blunt injury,” “penetrating injury,” and “TPC injury” suggests that the search interest is not limited to clinical symptoms; it also encompasses a need to obtain information about the injury mechanism and legal consequences. Mehra et al., who examined concussion searches, showed that search interest can change with seasonal and popular culture events, and that the quality and readability of the online information accessed are often inadequate [15].

The low and discontinuous RSV of the term “disability” should not be interpreted as meaning that the need for information about disability is low. Within the ICF framework, disability is a multidimensional concept encompassing function, activity, participation, and environmental factors [2]. Users may use different expressions related to specific diagnoses, disability health board reports, care, social assistance, accessibility, invalidity, or rights instead of the general term “disability.” Furthermore, studies showing ongoing digital inequalities in internet access and use by individuals with disabilities indicate that search engine data may underrepresent the information needs of this group [16,17]. WHO findings on health inequalities among individuals with disabilities also support the idea that digital visibility should not be equated with actual needs and service burden [3].

The regional results showing that reportable data for injury is available in more provinces and that the injury share is higher in all nine provinces where both terms could be measured is consistent with the national temporal pattern. However, it has been shown that online health information search behavior in Türkiye varies according to age, education, gender, region of residence, and frequency of internet use [6]. Therefore, differences at the provincial level can be influenced by factors such as population, internet access, digital literacy, and search behavior, as well as the frequency of the health problem. The fact that Google Trends does not generate value for low-volume provinces also limits comparisons, particularly across 59 provinces; regional RSVs cannot be considered a reliable indicator of epidemiological prevalence.

The concentration of related queries in both terms on definitional expressions such as “what is,” “types,” and “what does it mean” suggests that users need basic conceptual knowledge. Health literacy encompasses not only access to information but also the ability to understand, evaluate, and use information in decision-making [18]. The visibility of queries focused on regulations and patient rights in disability and on the Turkish Penal Code (TPC) in injury highlights the importance of presenting clinical explanations along with legal and rights information from a forensic medicine perspective. However, since related queries do not directly indicate user intent, these findings should not be considered proof of an information gap, but rather indicators pointing to content development priorities. The strongest aspect of the study is its simultaneous comparison of two clinically and forensically related concepts within the same country, period, category, and search type settings; and its analysis of the temporal series, the distribution at the provincial level, and the related queries simultaneously. The explicit statement of data cleaning decisions, the avoidance of treating low-volume values as absolute zero, and the presentation of the paired weekly comparison along with its current values also strengthen reproducibility and interpretability. The main limitations of the study stem from the nature of Google Trends data. RSV is not an absolute search count; it does not cover

information search behaviors outside of Google users, may be affected by sampling and algorithm updates, and does not include individual characteristics such as age, gender, education, disability status, and search intent [8-11,13]. The analysis was limited to only two broad Turkish search terms and the Health category; alternative queries such as “trauma”, “accident”, “disability”, “invalidity”, specific diagnoses, and rights/report statements were excluded. Finally, since search relevance was not compared with the number of injury cases, emergency room visits, disability health board applications, or forensic reports, no conclusions can be drawn in terms of causality and epidemiological information. In clinical and forensic practice, healthcare institutions should produce expert-supervised, simple, and up-to-date digital content for basic concepts in the context of “blunt injury”, “penetrating injury”, symptoms requiring emergency admission, things not to do in first aid, forensic documentation processes, and the TPC. In the field of disability, information on assessment regulations, health board processes, patient rights, appeal procedures, and access to services should be presented in accessible formats such as screen reader compatibility, easy-to-read language, subtitles, and sign language [3,5,15,16]. Information obtained by patients through online searches should be evaluated together and analyzed according to evidence-based clinical guidelines [5]. Google Trends assessment should be used as a complementary tool to quickly and easily identify the need for information; decisions made must be verified with emergency department, forensic case, and disability health board application data.

Conflict of Interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

The authors declare that they have received no financial support for the study.

Ethical Approval

The study used publicly available secondary data from Google Trends, anonymized, categorized, and aggregated. No individual identification information, IP address, demographic characteristics, medical records, or biological material was collected; no human participants were contacted or interfered with. Therefore, the study was not a human participant study and did not require ethical committee approval or informed consent. Data were reported only at the community and provincial level; no inferences were made regarding the attribution of low-volume searches to individuals.

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Original Article

Determination of gender from blood stains on different fabric types using a combined ATR-FT-IR spectroscopy and chemometric approach**Fatma Beyza Kula Yesilot¹, Dilek Salkım Islek², Eda Kiris², Nur Cebi³, Emel Hulya Yükseloglu²**¹*Bilişim Vadisi Technology Development Zone, Ecosystem Development Office, Kocaeli, Türkiye*²*İstanbul University-Cerrahpaşa Institute of Forensic Sciences and Legal Medicine, Department of Science, İstanbul, Türkiye*³*Yıldız Technical University, Faculty of Chemical and Metallurgical Engineering, Department of Food Engineering, İstanbul, Türkiye*

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**Abstract**

Aim: In forensic science, biological samples collected from crime scenes have a critical role in criminal profiling (such as determining gender, race, and age). Due to the time-consuming sample preparation processes required by traditional methods and their destructive nature, interest in ATR-FT-IR spectroscopy, which is based on molecular vibration and provides more rapid results, has increased in recent years. However, biological fluids at crime scenes are rarely found isolated; they are typically present on various surfaces such as fabric and glass. These surfaces affect the spectra of biological fluids and complicate the analysis. The aim of this study is to determine gender using ATR-FT-IR spectroscopy and chemometric methods from dried blood stains on different textile surfaces (cotton, denim, and polyester).

Materials and Methods: In this study, blood samples were collected from a total of 50 volunteers, including 25 women and 25 men. These samples were absorbed onto cotton, denim, and polyester fabrics and analyzed using ATR-FT-IR spectroscopy after a 24-hour drying period.

Results: Spectral analysis revealed variations in the characteristic band regions of the blood depending on the type of fabric. Principal Component Analysis (PCA) was applied to the obtained high-dimensional data set using the R package to reduce the number of dimensions; then, logistic regression analyses were performed using SPSS. Examination of the PCA loadings revealed that the spectral bands belonging to cholesterol and creatinine molecules have the potential to serve as discriminative biomarkers for gender differentiation.

Conclusions: The study results showed that logistic regression models built using only raw spectral data or simple variables had limited explanatory power for the gender-dependent variable. However, including the principal components obtained from PCA in the model had an effect that increased the model's explanatory power. When the substrate effect was evaluated, it was determined that blood samples on polyester fabric performed better in terms of accurate gender classification rates compared to cotton and denim surfaces. These findings highlight the importance of considering surface interactions when using spectroscopic methods in forensic serology.

Keywords: Chemometrics, ATR-FT-IR spectroscopy, gender determination, PCA, logistic regression

INTRODUCTION

Blood is one of the most ubiquitous and biologically significant forms of physical evidence encountered in forensic investigations. Accounting for approximately 8% of total human body weight, blood serves as a vital reservoir of both genetic and phenotypic information [1]. Physiologically, it is a highly complex biological fluid composed of an aqueous extracellular

matrix, known as plasma, which contains a variety of dissolved proteins, inorganic salts, and water [2]. Suspended within this plasma are the distinct cellular components: erythrocytes (red blood cells), leukocytes (white blood cells), and thrombocytes (platelets) [1]. From a forensic perspective, erythrocytes are of particular interest due to their high concentration of hemoglobin (Hb). This oxygen-transporting metalloprotein is structurally

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composed of a porphyrin heme group and globin protein subunits. Historically, forensic serology has relied heavily on the peroxidase-like activity of this heme group; preliminary screening and subsequent confirmatory tests exploit the oxidation-reduction reactions of heme to indicate the presence of blood in suspected forensic stains [3,4].

Despite their widespread operational use, traditional serological and chemical assays present notable limitations. Foremost among these is the destructive nature of the chemical reagents, which can permanently alter or consume limited biological evidence. Additionally, these conventional methods often require extensive sample preparation and can be susceptible to environmental degradation or false-positive results [4]. To circumvent the destruction of critical legal evidence, forensic researchers have increasingly transitioned toward non-destructive, label-free analytical methodologies. Spectroscopic modalities, in particular, have emerged as powerful tools for the biochemical profiling of trace evidence. Techniques such as fluorescence spectroscopy [5] and Raman spectroscopy [6] have demonstrated significant utility in biological analysis. More recently, attenuated total reflection Fourier transform infrared (ATR-FT-IR) spectroscopy has been widely adopted due to its ability to rapidly and accurately identify the presence and biochemical origin of blood with minimal to no sample preparation [7,8].

While the isolated spectroscopic analysis of neat blood is well-documented, forensic realities dictate that biological evidence is rarely encountered in pristine conditions. Bloodstains at crime scenes are most frequently deposited onto porous, everyday materials such as cotton, denim, or polyester apparel. Consequently, the biochemical signature of the blood is heavily convoluted by the spectral signals of the underlying matrix. Overcoming this substrate interference requires a thorough understanding of the textiles themselves. Previous studies have successfully employed vibrational spectroscopic methods, including infrared (IR) spectroscopy [9,10] and ATR-FT-IR [11], for the rigorous chemical characterization and classification of diverse textile fibers. Furthermore, advanced research has begun to explore the differentiation of various body fluid stains directly on fabric substrates utilizing FT-IR coupled with multivariate analysis [12].

Despite these advancements in substrate characterization and body fluid identification, a significant gap remains in the literature regarding the extraction of specific phenotypic characteristics from complex matrix-fluid mixtures. To date, no studies have comprehensively examined how the substrate effect influences the spectroscopic prediction of an individual donor's gender from a bloodstain. The extraction of such specific intelligence could provide crucial investigative leads in the absence of a DNA match.

Therefore, the aim of this study is to investigate the potential of ATR-FT-IR spectroscopy, combined with advanced chemometric data analysis, to accurately predict the gender of an individual

from bloodstains deposited on common textiles, specifically targeting cotton, denim, and polyester fabrics. By evaluating and mitigating the substrate effect, this research seeks to expand the non-destructive forensic capabilities of vibrational spectroscopy in complex real-world scenarios.

MATERIAL AND METHOD

Sample Collection and Preparation

Textile sample collection and preparation

Cotton, polyester, and gray denim fabrics were collected and cut into 4x4 cm² samples. They were washed in cold water in a conventional washing machine on a delicate cycle without detergent and dried without human contact to prepare them for analysis. The dried samples were placed in sterile petri dishes (15 mm x 60 mm).

Blood sample collection

The experiments and protocols used in the study were conducted in agreement with the decisions and guidelines of the İstanbul University-Cerrahpaşa Faculty of Medicine Clinical Research Ethics Committee (Decision No: 158845, 12/03/2020) after the committee's approval was received. Blood samples (5 mL) were collected from 50 healthy volunteers (25 women, 25 men) aged 18 years or older using non-anticoagulated tubes by venous injection.

Modelling

Blood samples from both women and men, collected into tubes without anticoagulant using a micropipette, were applied to cotton, polyester, and denim fabrics at 30 µL each. The same procedure was performed three times for each fabric type per individual. The fabrics with applied blood were dried overnight at room temperature. Sample preparation is shown in Figure 1.

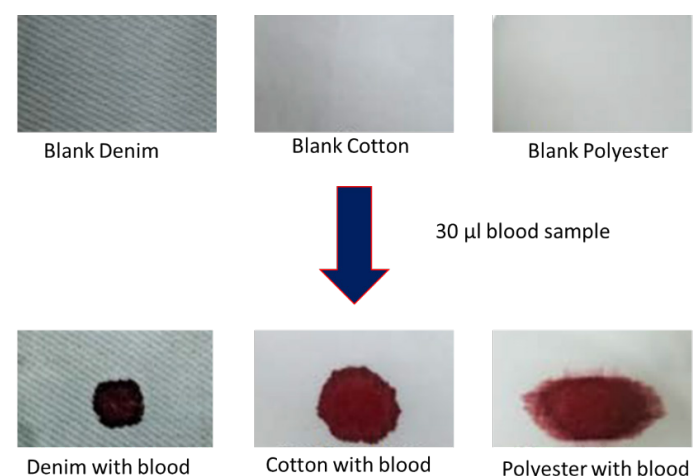


Figure 1. Sample preparation

ATR-FTIR Analysis

Dried blood stains on fabric were analyzed using an FT-IR spectrometer equipped with an ATR, DLATGS detector (Bruker

Tensor, Bremen, Germany) with diamond crystal. Spectra were obtained by performing 16 scans at 4 cm⁻¹ resolution in the mid-IR range of 4000-400 cm⁻¹ for each fabric type. Three replicates were performed for each volunteer on cotton, polyester, and denim fabric types. Before each spectrum was taken, the ATR crystal was cleaned with 70% ethanol, completely dried, and an air background was taken. Then, to minimize the effect of the fabric, an average spectrum was obtained by taking spectra from three areas of each fabric type without blood stains. Since blood does not spread homogeneously on the fabric, ten different measurements were taken from various regions of the blood-stained fabric to reduce the standard deviation between measurements, and an average spectrum was obtained.

Chemometric Analysis

Spectra were obtained and stored using OPUS 7.2 software (Bruker, Germany). Blank fabric spectra were automatically extracted from blood-spotted fabric spectra using OPUS 7.2 software. All chemometric procedures were performed using the R Package and

SPSS (version 15.0) software package. Pre-processing was applied to the data. Subsequently, dimension reduction was performed using PCA. After variable selection, modeling was performed by applying logistic regression to the data.

RESULTS

The age range, height, weight, and BMI data of the participants are provided in Table 1.

Table 1. Volunteers’ age, height, weight, and BMI values

Parameter	Man	Woman
Age range	22-58	23-55
Avg. of age	37.8 (±10.38)	36.3 (±11.01)
Avg. of height (m)	1.768 (±0.065)	1.629 (±0.073)
Avg. of weight (kg)	82 (±13.89)	63.32 (±12.65)
BMI	26.26 (Overweight)	23.89 (Normal)

The spectra of blank fabrics analyzed by ATR-FTIR for chemical characterization of fabrics are shown in Figure 2.

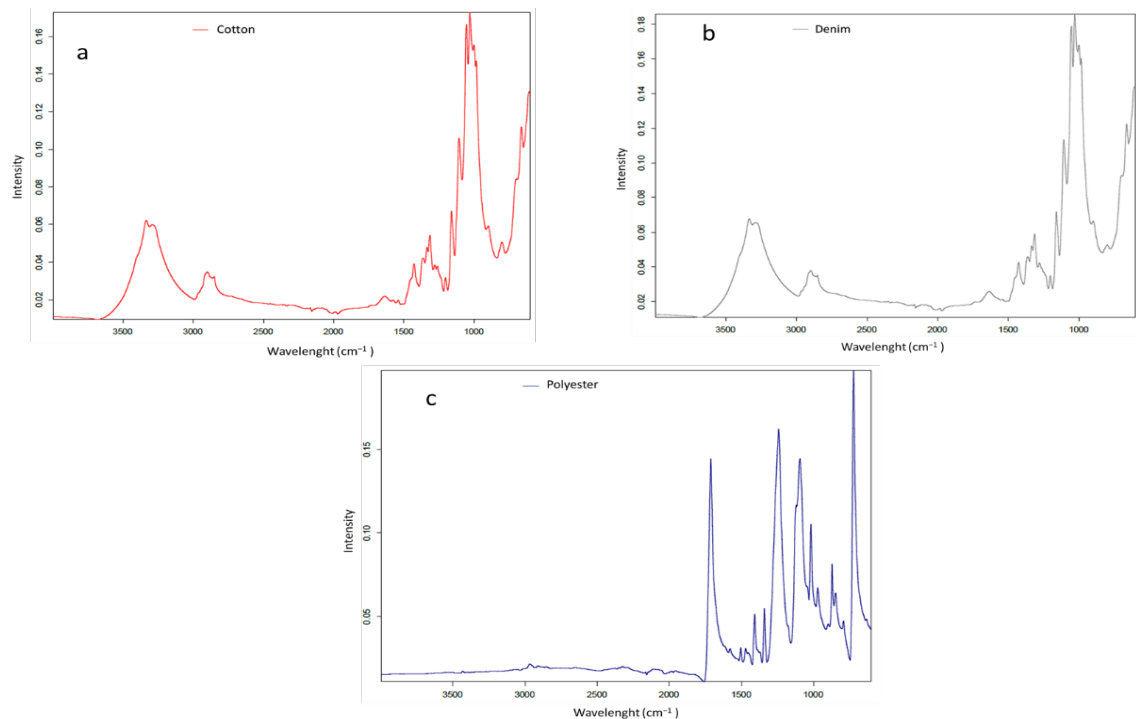


Figure 2. Spectra of a) cotton, b) denim, and c) polyester fabrics without bloodstains

Cotton and denim fabrics showed similar spectra, with the intense and broad band at 3550-3100 cm⁻¹ attributed to O-H stretching in cellulose, while the medium and broad band at 2900-2800 cm⁻¹ was attributed to C-H stretching. In the 1430-1300 cm⁻¹ region: 1429 cm⁻¹ indicates C-H plane vibration, 1368 cm⁻¹ represents C-H bending, and 1316 cm⁻¹ denotes C-H out-of-plane vibration. The sharp peaks at 1160 and 1108 cm⁻¹ of the ring structure forming cellulose result from asymmetric C-O-C bridge stretching. 1057 cm⁻¹ shows the asymmetric in-plane ring

stretching of the cellulose molecule, while the wavenumbers 1030 and 1000 cm⁻¹ show C-O stretching [13].

When the IR spectrum of polyester fabric is examined, the peak observed at a wavelength of 1715 cm⁻¹ due to C=O stretching is found to be distinctive. The medium intensity C-H stretching observed in the 2966 cm⁻¹ band shows the presence of an alkane group in the IR spectrum. The peak observed at 1241 cm⁻¹ is associated with vibrational movements related to

the aromatic ester functional group. The 1331 and 1021 cm^{-1} bands correspond to the carboxylic ester functional groups in the polyethylene terephthalate (PET) molecule [14]. The peak at the 720 cm^{-1} band corresponds to benzene derivatives in the IR spectrum. Additionally, since the polyester utilized in the experiment yielded spectral signals at 846, 973, and 1340 cm^{-1} , it is concluded that the PET is in the trans-conformation.

In this study, blood samples obtained from man and woman participants were applied to three different fabric types, and the resulting dried bloodstains were analyzed via ATR-FTIR spectroscopy. The IR spectra of the dried bloodstains (woman-man) on cotton fabric, along with the unstained cotton fabric control, are presented in Figure 3.

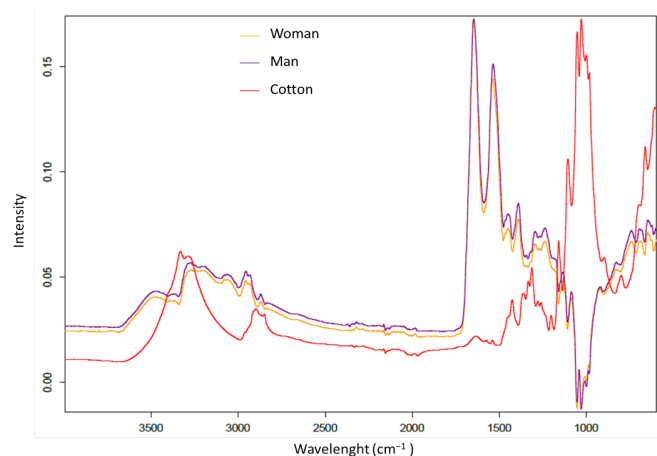


Figure 3. Dried blood stains on cotton fabric (woman-man) and the IR spectrum of cotton fabric without blood stains

Spectrum in Figure 3 shows that the broad bands observed in the 3600-3000 cm^{-1} region are N-H stretching vibrations characteristic of the amide functional groups in the structure of proteins, hemoglobin, and urea components found in blood. The C-H stretching vibrations specific to lipid molecules were detected as bands in the 3000-2800 cm^{-1} wavenumber region [15,16]. The Amide I area of the erythrocyte membrane proteins that form the characteristic structure of blood is distinct in the spectrum, producing strong peaks in the 1700-1620 cm^{-1} region [17]. Additionally, Amide II peaks formed as a result of the interaction between N-H in-plane bending and C-N stretching modes were observed in the 1450-1600 cm^{-1} region; this finding has been considered an important spectral difference that would distinguish dried blood stains from the spectrum of cotton fabric [17,18]. Likewise, two characteristic peaks corresponding to the Amide III area in the 1400-1200 cm^{-1} region were identified, and these peaks were observed in both the woman and man gender spectrums [17,18]. In the spectral fingerprint area between 1200 and 950 cm^{-1} , bands associated with the glucose molecule were observed [19,20].

Figure 4 shows the spectra of blood samples applied to denim fabric. The spectra were examined and no significant difference was found between the average spectra of dried blood stains from woman and man participants.

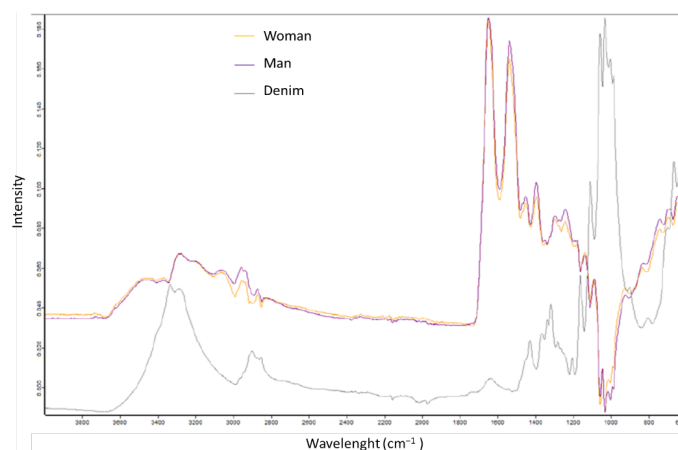


Figure 4. Dried blood stains on denim fabric (woman-man) and IR spectrum of denim fabric without blood stains

Following the spectral analysis of dried bloodstains on polyester fabric the presence of Amide I and Amide II bands—characteristic markers of blood—was identified in the IR spectrum as shown in Figure 5. However, due to spectral interference arising from the chemical structure of the polyester fabric, it was observed that the IR regions and frequency values associated with blood components exhibited variations compared to the spectra obtained from cotton and denim fabrics

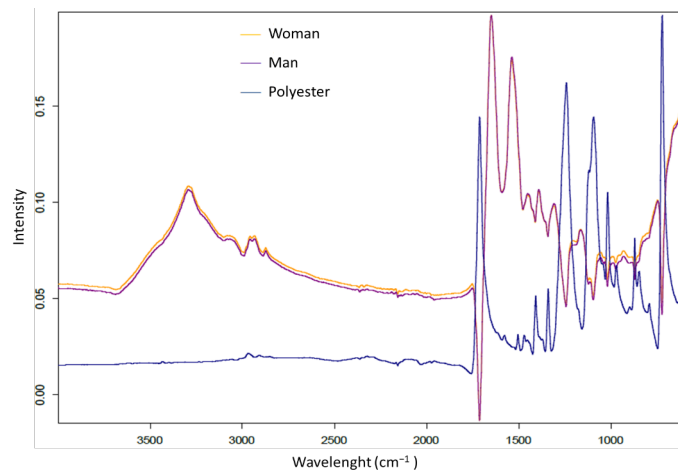


Figure 5. Dried blood stains on polyester fabric (woman-man) and IR spectrum of polyester fabric without blood stains

Chemometric methods were applied to distinguish between the genders of bloodstains and to compare the classification differences between fabrics, due to the fact that there is no visually noticeable difference in the spectrum of dried bloodstains on fabrics for both women and men.

Normalization was applied to the data obtained from the ATR-FTIR spectroscopic analysis of bloodstains deposited on denim, cotton, and polyester fabrics. Dimensionality reduction was performed on the pre-processed data using the PCA technique. According to the PCA results, a total of 150 principal components were identified. The first five principal components (PC1: 96.10392%; PC2: 0.09826654%; PC3: 0.03785720%; PC4:

0.02379158%; PC5: 0.01493602%) account for 97.852034% of the total variance, and the modeling was conducted using these

top five components. The factor loadings plot for the first five principal components is presented in Figure 6.

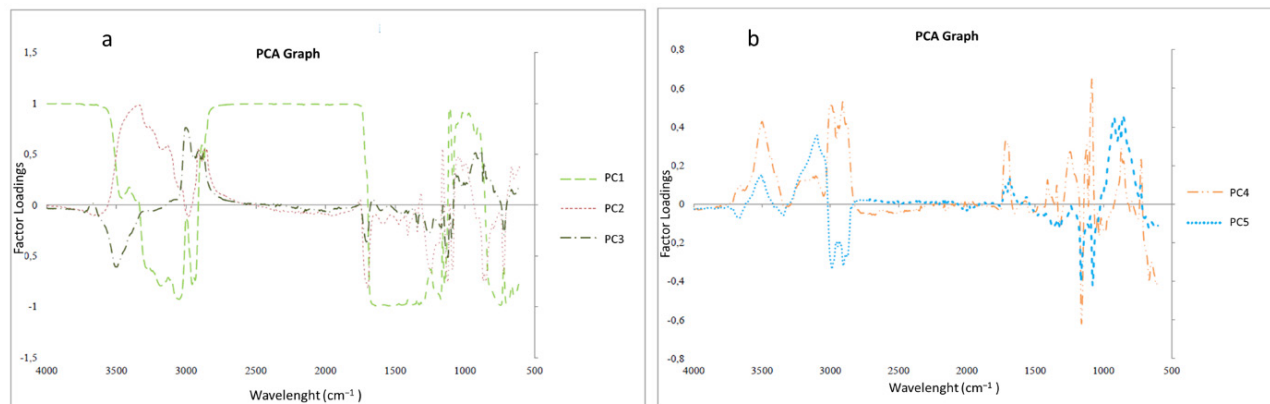


Figure 6. Factor loadings graph of the data set to which PCA was applied: a) PC1, PC2, and PC3, and b) PC4 and PC5

PC1 exhibits a significant correlation with the protein-derived Amide A region (3400–3300 cm^{-1}). In this compound, distinct peaks corresponding to the presence of creatinine (1107 cm^{-1}) [15] and DNA (1200–1000 cm^{-1}) [21] were observed. While the loading in the 2699–1711 cm^{-1} range was evaluated as resulting from the ATR crystal. PC2 was associated with lipid and carbohydrate structures in cholesterol and glucose. Positive correlations specific to cholesterol (2916 cm^{-1}), Amide III (1317 cm^{-1}), and glucose (1055–984 cm^{-1}) molecules were identified. In PC3, which serves as a discriminative factor for gender determination, lipid-derived C-H stretchings (3000–2800 cm^{-1}), the Amide I (1659 cm^{-1}) region, and DNA signals (1070–858 cm^{-1}) become prominent [15,16]. While PC4 reflected the C=O stretching of lipids (1750–1700 cm^{-1}) and the fabric background effect, PC5 exhibited a positive correlation with protein/hemoglobin-derived N-H and cellulose-derived O-H stretchings (3600–3000 cm^{-1})

According to the PCA results, five principal components were identified and displayed on the PCs with distribution graphs of the man and woman's data sets according to gender. The graphs of the women's and men's data sets on the components are shown in Figure 7.

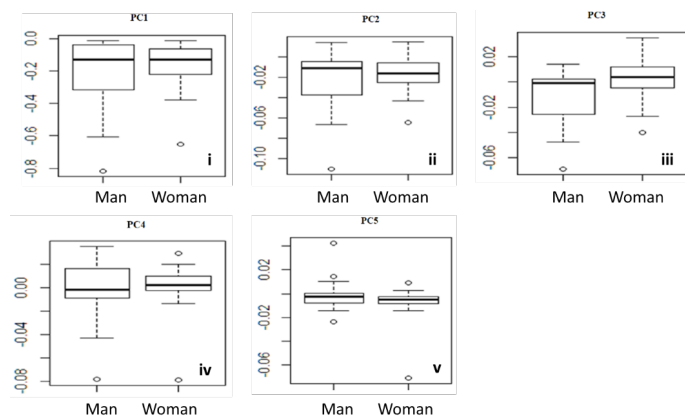


Figure 7. Boxplot graphs of the woman and man data sets on the i) PC1, ii) PC2, iii) PC3, iv) PC4, and v) PC5 components

The graphs for the principal components PC1, PC2, PC3, and PC4 were examined, and it was observed that the data set for man participants showed a higher variance compared to women and that outliers were located further from the center of the distribution. It was found that the data related to gender groups significantly collided in these components; this points to the fact that it is statistically difficult to make a clear distinction between genders based on the relevant principal components. However, when examining the distributions on the PC5 component, it was found that the woman and man's data sets had a more similar and homogenous structure compared to the other components, but outliers were also maintained in both groups.

In this study, PCA was primarily employed for the exploratory evaluation of the data structure and to identify the specific wavenumbers that account for the dominant variance within the ATR-FT-IR spectra, rather than to achieve direct class separation. Accordingly, PCA loading plots served as the principal analytical tool to elucidate the contributions of individual spectral variables to the overall variance. Although PCA score plots were systematically examined, no distinct clustering or spatial separation between the male and female blood samples was observed. This lack of differentiation is further corroborated by the results of the logistic regression analysis. As a supervised classification method, logistic regression also failed to yield a statistically significant separation between the two groups. This concurrent outcome strongly suggests that any gender-dependent spectral variations within this particular dataset are neither highly pronounced nor linearly separable. Consequently, it is methodologically consistent that an unsupervised technique such as PCA would similarly be unable to produce a meaningful class distinction under these parameters.

In this study, logistic regression models were established using scores obtained from PCA in order to predict gender in blood samples obtained from denim, cotton, and polyester fabric surfaces. For each fabric type and the general dataset, gender

was defined as the dependent variable, and the first five principal components (PC1-PC5) were defined as independent variables. The logistic regression method without a constant term was preferred in the analyses. The comparison of R^2 , overall

significance, and classification success of the logistic regression models is given in Table 2, and the comparison of variable coefficients and significance levels for the logistic regression models is given in Table 3.

Table 2. Comparison of R^2 values, overall significance, and classification accuracy across logistic regression models

Model	-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2	Chi-squared (χ^2)	SD	p (Sig.)	Correct classification rate
General model	62.343	.130	.174	6.181	8	.627	58.0
Cotton	63.851	.104	.138	4.801	8	.779	64.0
Denim	62.343	.130	.174	12.255	8	.140	56.0
Polyester	62.501	.127	.170	6.947	8	.542	68.0

Table 3. Comparison of coefficients and significance levels for logistic regression models

Model	Variables	B	S.E.	Wald	SD	p	Exp(B)=ODDS
General model	PC1	.265	.245	1.167	1	.280	1.304
	PC2	-.426	.619	.475	1	.491	.653
	PC3	.233	.244	.912	1	.340	1.263
	PC4	.070	.490	.021	1	.886	1.073
	PC5	.546	.358	2.328	1	.127	1.727
Cotton	PC1	.021	.015	2.160	1	.142	1.022
	PC2	.010	.049	.043	1	.836	1.010
	PC3	.056	.067	.688	1	.407	1.058
	PC4	.049	.062	.617	1	.432	1.050
	PC5	-.095	.083	1.321	1	.250	.909
Denim	PC1	.014	.009	2.263	1	.132	1.014
	PC2	.006	.052	.014	1	.907	1.006
	PC3	.035	.031	1.331	1	.249	1.036
	PC4	-.039	.086	.209	1	.647	.961
	PC5	.051	.095	.286	1	.593	1.052
Polyester	PC1	.009	.019	.213	1	.645	1.009
	PC2	-.042	.035	1.468	1	.226	.959
	PC3	.134	.072	3.421	1	.064	1.143
	PC4	.017	.102	.027	1	.869	1.017
	PC5	.146	.103	2.029	1	.154	1.158

Cotton: Upon examining the goodness-of-fit values for the model developed for cotton fabrics, it was observed that the five principal components explained 10.4% of the variance in the gender variable according to the Cox & Snell R^2 , and 14.0% according to the Nagelkerke R^2 . The overall significance test, conducted to evaluate the collective significance of the model coefficients, indicated that the model was not statistically significant ($p > 0.05$). This finding is consistent with the acceptance of the null hypothesis (H_0), demonstrating that the principal components do not have a determinative effect on gender prediction on cotton fabric surfaces. Regarding classification performance, the Correct Classification Rate (CCR) was calculated at 64.0%. The lack of statistical significance suggests that this rate stems from random assignment and indicates low predictive reliability. Evaluation of individual variable contributions revealed that the p-values for all parameters exceeded the significance threshold ($p > 0.05$).

Furthermore, although the Odds Ratios (Exp(B)) suggested that components other than PC5 exert a positive effect on the gender variable, these effects were determined to be statistically non-significant.

Denim: In the model constructed for denim fabric surfaces, the explanatory power of the independent variables on the dependent variable was found to be 13.0% according to Cox & Snell R^2 and 17.4% according to Nagelkerke R^2 . Similar to the cotton fabric model, the p-value in the global model significance test exceeded the significance threshold ($p > 0.05$), leading to the conclusion that the model is entirely non-significant. The Correct Classification Rate (CCR) calculated for denim fabric remained at 56.0%. This rate indicates that the model's predictive performance is indistinguishable from random chance and does not provide a reliable classification. In the analysis of individual

variables, all parameters were found to be non-significant; based on the Odds Ratios, it was determined that all components except for PC4 exerted a positive effect.

Polyester: In the model constructed for polyester fabrics, the coefficients of determination were calculated as 12.7% for Cox & Snell R^2 and 17.0% for Nagelkerke R^2 . In the overall significance test, the H_0 hypothesis, which states that ‘the independent variables for polyester fabric are insufficient to explain the gender variable,’ was accepted; consequently, the model was found to lack statistically significant predictive power ($p > 0.05$). Although the polyester fabric model achieved the highest Correct Classification Rate at 68.0% compared to the other fabric types, this performance lacks statistical significance due to the overall non-significance of the model. None of the individual parameters were found to be significant ($p > 0.05$), and it was determined that all components except for PC2 exerted a positive effect.

General Model and Evaluation: In the general model, which incorporated the entire dataset regardless of fabric type, the explanatory power of the five principal components for the gender variable was determined to be 13.0% via Cox & Snell R^2 and 17.4% via Nagelkerke R^2 . Following the overall significance test ($p > 0.05$), it was observed that the independent variables were insufficient for gender prediction, leading to the acceptance of the null hypothesis (H_0). The Correct Classification Rate (CCR) for the general model was 58.0%, suggesting that gender assignment was essentially stochastic and that the method lacks sufficient reliability for forensic applications. Upon individual examination of the model parameters, all p-values were found to be greater than 0.05, indicating non-significance. Nevertheless, based on the Odds Ratios (Exp(B)) it was noted that the PC1, PC3, PC4, and PC5 components exerted a positive effect on the model.

DISCUSSION

This study aims to estimate gender from dried bloodstains on cotton, denim, and polyester fabric surfaces, which are frequently encountered in forensic cases, using ATR-FT-IR spectroscopy and chemometric methods. The study was designed to use blood samples without anticoagulants on selected fabric types, considering worldwide manufacturing volumes and everyday usage prevalence [22,23] to simulate crime scene conditions. Analyses were performed on dried samples [24] and on data where the fabric spectrum was removed as background to eliminate the masking effect of water molecules.

Based on the spectral data studied, it was observed that the physical structure of the fabrics (whether porous or non-porous) directly affects blood absorption and, consequently, the intensity of the spectral bands. In cotton and denim fabrics with a porous structure, the absorption of blood by the fibers reduced the blood concentration remaining on the surface, causing the band intensities in the ATR spectrum to decrease. In contrast, on polyester fabric—characterized by its hydrophobic and non-porous structure—the tendency of blood to exhibit bead formation [25] facilitated the development of a denser blood film. Consequently, this phenomenon allowed for the highest

absorption intensity to be obtained from this specific fabric type.

Across all fabric types, the Amide I ($1700\text{--}1620\text{ cm}^{-1}$), Amide II ($1450\text{--}1600\text{ cm}^{-1}$), and Amide III ($1400\text{--}1200\text{ cm}^{-1}$) bands, which signify the protein structure in blood, were distinctly observed. These findings are consistent with similar studies in the literature [7,22]. However, the band observed at approximately 3292 cm^{-1} in polyester fabric, attributed to the Amide A region, could not be detected in cotton and denim fabrics. As noted by DeJong et al. (2015), this is evaluated to result from the masking of the Amide A region by the intense absorption of cellulosic hydroxyl (O-H) bonds inherent in the structure of cotton fabrics [26]. Similarly, while the weak peak at 1112 cm^{-1} in the polyester spectrum indicates the presence of hemoglobin the dominant signals of the substrate in the other fabrics hindered the detection of these specific details [27].

Following the PCA performed to reduce the dimensionality of the spectral data and to explain the variance, it was determined that the first five principal components (PCs) accounted for 97.85% of the total variance. Examination of the PC factor loadings revealed spectral traces of potential biomarkers—including creatinine, cholesterol, glucose, and lipids—that could elucidate sexual dimorphism. The peaks observed in PC1 and PC2 within the $1230\text{--}1100\text{ cm}^{-1}$ range, specifically at 1107 cm^{-1} are considered to be associated with the creatinine molecule, which has been reported in the literature to be higher in males than in females [28,29]. Additionally, lipid/cholesterol bands in the $3000\text{--}2800\text{ cm}^{-1}$ region contributed to the variance. For PC3, the loadings are explained by gender-dependent physiological differences in glucose and lipid metabolism [30,31] and age-related changes in cholesterol [32]. Given the mean ages of the participants in the study group (Male: 37.8, Female: 36.3), cholesterol levels were expected to be a discriminating factor. However, despite these expected biochemical differences, an analysis of the resulting PC score plots showed that the male and female datasets did not exhibit distinct clustering and largely overlapped. As reported in studies by Takamura et al. and Mistek et al., this situation can be attributed to the inherent heterogeneity and individual variations of biological samples (blood, urine) masking the mean differences between genders [4,33].

In the logistic regression models constructed using the components derived from PCA, it was observed that polyester fabric exhibited a lower ‘-2 Log Likelihood’ value and the highest correct classification rate (68%) compared to cotton and denim fabrics. Although this partial success is attributed to the fact that polyester causes less masking of the spectral data, global significance tests revealed that the p-values for all models remained above the threshold for statistical significance ($p > 0.05$). The results demonstrate that the PCA-based variable selection and the subsequent logistic regression models do not possess sufficient discriminative power for gender prediction under the current sample set and experimental conditions. While an examination of the Odds Ratios indicated positive directional effects for certain components (specifically PC1, PC3, and PC4), these effects were determined to be statistically non-significant

The failure to achieve the high accuracy rates targeted in this study stems from several experimental and instrumental constraints;

1. The application of blood to the fabric via the dripping method and the subsequent “coffee ring” effect during the drying process led to a non-homogeneous distribution within the stain. As noted by McCutcheon et al., while dip-coating techniques provide more uniform surfaces, the dripping method was preferred in this study to maintain ecological validity relative to crime scene realities. This approach resulted in high variance among spectra acquired from different regions of the same stain [34].
2. The lack of controlled temperature and humidity during the drying process may have induced degradation in blood proteins and macromolecules, potentially leading to spectral shifts [35,36]
3. The constant pressure applied by the ATR accessory altered the crystal-to-sample contact and, consequently, the penetration depth across fabrics with different thicknesses and weaving characteristics (e.g., denim vs. polyester). This variation complicated the standardization of spectral intensities [11]
4. In this study, PCA—which maximizes variance—was utilized for variable selection. However, to enhance classification success, the use of more advanced “Variable Selection” techniques that perform goal-oriented wavelength selection, such as Genetic Algorithms (GA), is recommended for future studies to eliminate noise and improve model performance [4,37]

Despite the limited classification success achieved in this study due to the spectral masking challenges posed by blood-fabric interactions, recent research in the literature demonstrates that ATR-FTIR spectroscopy and chemometric methods hold high potential for sex determination in forensic sciences. For instance, studies conducted on hair samples have proven that the integrated use of ATR-FTIR spectroscopy and chemometric analyses is highly effective in distinguishing between male and female hair. Similarly, high accuracy rates in sex classification and prediction within a forensic context have been achieved through the chemometric analysis of spectral data obtained from fingernail clippings. Unlike blood or complex body fluids, the combined use of machine learning and ATR-FTIR on solid biological samples with less matrix interference, such as human skin, also offers a novel and successful perspective for gender determination. These findings support the notion that if the substrate masking effect encountered in our study is overcome, or if more advanced machine learning algorithms are employed beyond PCA, ATR-FTIR could achieve similar success in predicting sex from biological traces on textiles [38-41].

CONCLUSION

This study investigated the feasibility of sex determination from dried bloodstains on cotton, denim, and polyester textile surfaces—commonly encountered at forensic crime scenes—

utilizing ATR-FTIR spectroscopy and chemometric methods (PCA and Logistic Regression). The findings indicated that the logistic regression models constructed on PCA scores did not produce statistically significant results ($p > 0.05$), and the sex classification accuracies (ranging from 56% to 68%) did not reach the reliability levels required by forensic standards. When comparing fabric types, polyester, which allows blood to remain on the surface due to its hydrophobic nature, provided more distinct spectral data and relatively higher classification success compared to the cellulosic and absorbent cotton and denim fabrics. However, the dominant masking effect of substrate (fabric) signals on the blood spectrum limited the clear differentiation of sex-specific biomarkers (e.g., creatinine, cholesterol) across all surfaces. Furthermore, it was concluded that the heterogeneous distribution of blood during the drying process and physical variables in the sample preparation phase adversely affected model performance by increasing spectral variation. Consequently, under the current experimental conditions, sex determination from blood on textiles via ATR-FTIR spectroscopy has not yet reached sufficient maturity for practical applications. While this study demonstrates the exploratory potential of ATR-FT-IR spectroscopy for this application, the findings must be interpreted in light of certain limitations. Specifically, 50 individuals is relatively limited when considering the extensive natural biological variability present in whole blood. Consequently, subsequent studies utilizing expanded sample sizes are essential to confirm these results and improve the robustness of the predictive models. In future studies, the use of more sensitive sampling techniques to minimize fabric interference and the integration of advanced chemometric algorithms that perform goal-oriented variable selection, such as Genetic Algorithms (GA), may enhance the discriminative power of the method.

Conflict of Interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

The authors declare that they have received no financial support for the study.

Ethical Approval

Approved by the İstanbul University-Cerrahpaşa Faculty of Medicine Clinical Research Ethics Committee (03/12/2020-158845); all participants provided informed consent.

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Original Article

Evaluation of disability reports requested by judicial authorities for individuals under 18 years of age from the department of forensic medicine between 2023–2025**İD Mesut Yılmaz, İD Erkal Gumusboga, İD Abdulkерim Yayla, İD Ramazan Ozalp, İD Berkay Tertemiz***İnönü University, Department of Forensic Medicine, Faculty of Medicine, Malatya, Türkiye*

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**Abstract****Aim:** This study aimed to retrospectively evaluate disability reports prepared for individuals aged 0–18 years due to injury-related disability in terms of trauma origin, demographic characteristics of individuals, injury sites, and the presence of special needs.**Material and Methods:** In this retrospective study, 47 cases under the age of 18 for whom disability reports were requested by courts from the Department of Forensic Medicine, İnönü University between 2023–2025 were evaluated in accordance with judicial requests. Evaluation parameters were determined as age, gender, nationality, season, injury sites, bone fracture, requested regulation, and injury origin. The obtained data were analyzed using IBM SPSS Statistics 22.**Results:** Of the cases evaluated in accordance with disability regulations, 33 were male (70.2%) and 14 were female (29.8%). The mean age of the cases was calculated as 11.7. It was observed that traffic accidents constituted the largest proportion of injuries, and in 42 of 47 cases (89.4%), disability occurred due to traffic accidents. Bone fractures were observed in 40 of the cases (85.1%). It was observed that 16 of the 47 cases (34%) occurred in the summer season.**Conclusion:** The determination of traffic accidents as the most common cause of disability highlights the importance of traffic safety in our country. It is of our opinion that taking appropriate measures to minimize injuries, ensuring effective deterrence, full compliance with occupational safety measures and traffic rules, and awareness trainings will minimize these adverse outcomes and prevent anatomical and functional losses that individuals may experience.**Keywords:** Forensic Medicine, disability assessment, injury**INTRODUCTION**

Childhood is the stage of life in which physical, psychological, and cognitive development progresses most rapidly. Trauma occurring during this period may lead not only to acute medical problems but also to serious health problems that may result in permanent physical or psychosocial effects. According to TurkStat data, children constituted 25.5% of the population of Türkiye in 2024 [1].

According to Türkiye Traffic Road Accident Statistics (2014), 11.1% of deaths (391 children) and 18.2% of injuries (51,850 children) were in the 0–17 age group. Approximately 0.2% of children aged 0–19 in Türkiye in 2014 were injured due to traffic accidents. In a study reflecting national data in Türkiye, it

was found that 0.7% of children aged 7–14 were injured due to traffic-related causes [2].

The World Health Organization (WHO) defines disability as “any restriction or lack of ability to perform an activity in the manner or within the range considered normal for a human being” [3]. According to the WHO 2008 report, each year 950,000 children die due to injuries, and 10–30 million children are forced to live with permanent disability. This corresponds to more than 100 preventable child deaths every hour. It has been observed that unintentional injuries, including traffic accidents, burns, falls, drowning, and poisoning, constitute nearly 90% of these cases, and traffic accidents alone are the leading cause of death among individuals aged 15–19 and the second leading cause of death

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among children aged 5–14 [4]. Data from the US Centers for Disease Control and Prevention (CDC) also show that childhood injuries hold an important place among preventable causes of death and disability [5].

In this study, it was aimed to retrospectively evaluate disability reports issued for individuals aged 0–18 years due to injury in terms of trauma origin, demographic characteristics, injury sites, and the presence of special needs.

MATERIAL AND METHODS

For this study, approval was obtained from the Scientific Research and Publication Ethics Committee of İnönü University Health Sciences Scientific Research Ethics Committee (Session Date: 14-10-2025, Session Number: 13, Decision Number: 2025/8329).

In our study, 47 cases under the age of 18 for whom disability reports were requested by courts from the Department of Forensic Medicine, İnönü University between 2023–2025 were retrospectively examined.

In this study, the evaluation was carried out in accordance with the “Regulation on the Assessment of Special Needs for Children” published in the Official Gazette dated 20 February 2019 and numbered 30692, the “Guide on Disability Ratios of the Regulation on Disability Assessment for Adults” published in the Official Gazette dated 20.02.2019 and numbered 30692, the “Regulation on Impairment Criteria, Classification and Health Board Reports for Persons with Disabilities” published in the Official Gazette dated 30.03.2013 and numbered 28603, and the “Regulation on Determination of Loss of Working Capacity and Occupational Earning Capacity” [6–9].

In our study, 47 individuals under 18 years of age were evaluated in terms of demographic parameters, trauma origin, month and season of injury, year, anatomical injury site, presence of bone fracture, injury type, and need for special care. Cases evaluated for disability determination and for which percentage calculation was performed were included in the study, while repeated applications, cases for which preliminary forensic reports were issued due to lack of evaluable medical documentation, and reports requested for purposes other than disability determination were excluded.

The obtained data were analyzed using IBM SPSS Statistics 22. Descriptive statistical methods were used in statistical analysis.

Results

It was observed that 95.7% of the cases included in this study were citizens of the Republic of Türkiye and 4.3% were foreign nationals. Therefore, no evaluation was made in this regard since a comparison based on nationality would not be statistically significant. The mean age of the cases was 11.7. A marked difference in favor of the male gender was observed between genders. Of the cases, 33 (70.2%) were male and 14 (29.8%) were female.

Of the total 47 cases included in the study, traffic accidents were the leading cause of injury in 42 cases (89.4%). Injury occurred due to sharp object injuries in 2 cases (4.3%), due to falls in 1 case (2.1%), and due to other causes in 2 cases (4.3%) (Table 1).

Table 1. Cause of Injury

Cause of injury	Number (%)
Traffic accident	42 (89.4)
Sharp force injury	2 (4.3)
Fall	1 (2.1)
Other	2 (4.3)
Total	47 (100)

As a result of injury, bone fractures occurred in 26 of 33 males, while bone fractures were observed in all 14 females (Table 2).

Table 2. Bone fracture-gender distribution

Bone fracture-gender distribution	Bone fracture present (%)	No bone fracture (%)	Total (%)
Male	26 (78.8)	7 (21.2)	33 (100)
Female	14 (100)	0 (0)	14 (100)
Total	40 (85.1)	7 (14.9)	47 (100)

It was observed that 34% of the cases occurred in summer, 27.7% in autumn, 21.3% in winter, and 17% in spring (Figure 1).

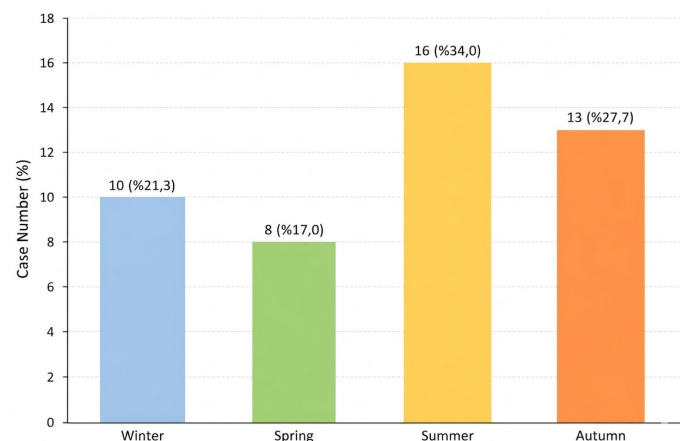


Figure 1. Seasonal distribution of the cases

In both genders, the most common injury site was extremities (45%). Body regions evaluated for disability ratio determination were classified as musculoskeletal system, nervous system, Ear, Nose, and Throat (ENT), skin, urogenital system, respiratory system, and visual system. In both genders, the most frequently evaluated system was the musculoskeletal system (40%), while the least frequently evaluated systems were the respiratory system (1.4%) and visual system (1.4%). In 11 cases, no traumatic lesion, anatomical or functional loss that would constitute disability under the regulations requested by judicial authorities was found, or the existing sequelae were found to have healed without causing permanent disability.

Among the total 47 cases under 18 years of age sent by courts, disability reports were requested under the “Regulation on the Assessment of Special Needs for Children” [9] in 19 cases, under the “Guide on Disability Ratios of the Regulation on Disability Assessment for Adults” [6] in 20 cases, under the “Regulation

on Impairment Criteria, Classification and Health Board Reports for Persons with Disabilities” [8] in 7 cases, and under the “Regulation on Determination of Loss of Working Capacity and Occupational Earning Capacity” [7] in 1 case (Table 3).

Table 3. Regulations requested by the courts

Regulation requested by the courts	Number (%)
Regulation on the assessment of special needs for children	19 (40.4)
Field guide on disability rates of the regulation on disability assessment for adults	20 (42.6)
Regulation on impairment criteria, classification and health board reports for persons with disabilities	7 (14.9)
Regulation on procedures for determination of loss of working capacity and occupational earning capacity	1 (2.1)
Total	47 (100)

DISCUSSION

Childhood permanent functional loss constitutes a more complex clinical and legal process compared to adults due to growth and developmental potential. Etiologically, traffic accidents were the leading cause in 42 of 47 cases (89.4%). Krzysztof Goniewicz et al. reported in their study published in 2017 that traffic accident-related injuries are more common in children than cancer and birth defects and are a leading cause of death [10].

Many causes lead to injury in children; however, motor vehicle accidents cause the highest number of serious injuries and deaths in all pediatric age groups [11]. Motor vehicle accidents, including passenger, bicycle, and pedestrian injuries, account for approximately half of childhood injury-related deaths [12]. The primary cause of disability in our study was also determined to be traffic accidents.

In our study, 70.2% of the cases (n=33) were male. This high rate is consistent with studies by Ural et al. and Yazıcı and Can, which emphasize male predominance in childhood injuries [5,13]. The main reason is considered to be the higher participation of male children in risky outdoor activities. In the study of E. Verhagen et al. on physical activity and sports-related injuries in children aged 10–12 years, a higher injury rate was reported in girls compared to boys [14]. Although our study is generally consistent with the literature, the difference in Verhagen et al.’s findings may be attributed to sociocultural and geographical differences.

Regarding seasonal distribution, the highest rate of cases was observed in summer with 34% (n=16). Similarly, Eva Jespersen et al. showed that musculoskeletal extremity injuries increased by 46% and injury prevalence by 32% in summer compared to winter in school-aged children [15]. This is explained by increased outdoor activity during holidays.

In the study of Hekimoğlu et al., traffic accidents constituted the majority of cases (91.6%), male gender predominance was observed (69.9%), and cases most frequently occurred in summer

(33%), with pelvis and lower extremity injuries being most common [16]. Ahmer Zaeema and Siddiqui Aisha reported that bone injuries occurred in 79.8% of cases and lower extremities were the most affected body region (57.1%) [17], which is consistent with our findings.

In one case, a disability report was issued under the “Regulation on Determination of Loss of Working Capacity and Occupational Earning Capacity” [7] the largest tertiary care hospital of Karachi. Method A descriptive cross-sectional study was done in January-March 2019 among 371 respondents aged 15-65 years. Study participants were recruited through non-probability convenience sampling. A structured questionnaire was used to collect data on sociodemographic variables and type, severity and nature of injury. Chi Square test was used to determine the significant difference between using safety precautions with body parts affected. All analysis was performed on SPSS version 20. Results Out of 371 study participants, 64.4% (n=239 and it was observed that the femoral shaft fracture due to accident had completely healed, with no limitation in hip and knee joint range of motion, and a loss of occupational earning capacity was determined. It was also observed that the same individual would not receive a disability rating under other regulations, indicating significant differences between regulations and that inappropriate regulation selection may lead to loss of rights. Therefore, standardization of guidelines used in disability calculations, evaluation based on the regulation in force at the time of injury, and consistent use of a single evaluation system are important to prevent loss of rights.

CONCLUSION

Consistent with the literature, it was observed that traffic accidents were the most common cause of injury among cases referred for disability determination by judicial authorities, that these injuries occurred more frequently in summer, and that they were more common in males. In individuals aged 0–18 years, preventive education on traffic rules and traffic safety, awareness activities, and inspections conducted more intensively during

summer months through verbal and written communication channels are considered to reduce injuries to a minimum, and the use of standardized evaluation methods is considered to minimize the risk of loss of rights.

Conflict of Interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

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Ethical Approval

Approval was obtained from the Scientific Research and Publication Ethics Committee of İnönü University Health Sciences Scientific Research Ethics Committee (Session Date: 14-10-2025, Session Number: 13, Decision Number: 2025/8329).

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Review Article

A legal analysis of violence in healthcare Zeynep Ugurlu,  Emel Hulya Yukseloglu*Istanbul University-Cerrahpaşa, Institute of Forensic Sciences and Legal Medicine, İstanbul, Türkiye*

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**Abstract**

Violence is a major public health issue that continues to grow both worldwide and in our country. Although violence is something we face in every area of life, it is very common in the healthcare field as well. Violence in healthcare, which has become a constant and hot topic lately, seriously affects the physical and mental health of doctors and all healthcare workers. This situation also significantly impacts the quality of healthcare services. The World Health Organization (WHO) considers this issue not just a problem for doctors and healthcare staff, but an urgent health crisis that directly affects the well-being of the entire society. Violence in healthcare has become a massive problem in other countries, just like it is in ours. It is clear that violence in the health sector has increased in our country, especially in recent years, appearing frequently in the media and leading to many legal disputes. Even though these cases have gone to court, it has been observed that the deterrent factor is not at a sufficient level. In this study, the types of violence in healthcare, the current and newly made legal regulations in our country, the rights of healthcare workers against violence, how a victim of violence should manage the process, and suggestions for solving violence are discussed.

Keywords: Violence, violence in healthcare, healthcare personnel**INTRODUCTION**

Violence, which is seen as a violation of human rights, is defined as a behavior applied for the purpose of physical coercion or threat—regardless of ethnic origin, class, religion, social status, cultural, economic, or geographical boundaries—directed at oneself or someone else, which may lead to death, injury, mental damage, or developmental disorders [1,2]. Violence has been defined by the World Health Organization as the intentional use of physical or psychological power against oneself, another person, a group, or a community, which results in (or is highly likely to result in) injury, death, psychological harm, developmental delay, or deprivation [3]. At the same time, violence is a public health problem that directly affects the well-being of communities [4]. The World Medical Association defines violence in healthcare as an international emergency that shakes the foundations of health systems and critically affects the health of patients [5]. It has also been defined as any behavior that puts a healthcare worker at risk and includes

verbal abuse, threatening behavior, or assault by a patient or a member of the community [6]. It is known that violence, which is seen in every field, carries a higher risk for healthcare workers compared to other professional groups [7,8]. Additionally, it should not be forgotten that every single healthcare worker is a potential candidate for violence [9]. From the perspective of the World Health Organization, the concept of "healthcare workers" includes physicians, assistant physicians, multi-tasked health assistants, dentists, dental assistants, pharmacists and pharmacist assistants, veterinarians, animal health assistants, midwives, assistant midwives, assistant nurses, nurse aides, physiotherapists, laboratory technicians and assistants, medical radiology technicians and assistant technicians, as well as administrative staff, technical staff, and other personnel who serve alongside or participate in the service [10]. Accordingly, all administrative or technical personnel working in health institutions and organizations are also included in this scope [11]. This study adopts a narrative review approach and aims to provide a critical and analytical evaluation of violence in

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healthcare in the Turkish context. Unlike purely descriptive studies, this research offers a comparative and critical synthesis of the literature and identifies key gaps in current legal and institutional frameworks.

Methodology

This study adopts a narrative review methodology to examine the phenomenon of violence in healthcare within the Turkish context. The primary objective is to synthesize existing literature, evaluate legal frameworks, and identify gaps in current research and practice.

A comprehensive literature search was conducted using both international and national academic databases, including PubMed, Scopus, Google Scholar, and ULAKBİM. The search focused on studies published between 2000 and 2025 to ensure both historical perspective and contemporary relevance.

The following keywords were used during the search process: “violence in healthcare,” “healthcare workers,” “occupational safety,” “workplace violence,” “Turkish Penal Code,” and “health law.”

The inclusion criteria were defined as: Peer-reviewed academic articles, legal and policy-related documents, studies focusing on healthcare violence and its legal, social, or institutional dimensions, publications available in English or Turkish. Studies that lacked scientific rigor, were not directly related to healthcare violence, or consisted solely of opinion-based content without empirical or legal grounding were excluded.

Rather than providing a purely descriptive summary, this study applies a thematic and comparative approach. The selected literature was categorized under key themes such as:

Types and causes of violence, legal regulations and enforcement, institutional responses (e.g., White Code system) and preventive strategies.

This approach enables a critical synthesis of findings, highlighting consistencies, contradictions, and gaps in the literature. The methodology aims to enhance the analytical depth of the study and provide a foundation for evidence-based recommendations.

Types and Causes of Violence in Healthcare

Violence is evaluated as physical and psychological according to how it occurs [8]; however, some studies show that types of violence consist of verbal violence, physical violence, and sexual harassment. In different cultures, racism is also included among the types of violence [12]. It has been stated that violence covers a wide range from verbal abuse to physical intervention, and it is impossible for healthcare personnel to predict or intervene in violence beforehand [13].

According to various studies, there are many reasons for the violence occurring between healthcare workers and patients and/or their relatives, and these acts of violence can cause

psychological, physical, economic, and social harm [14]. These reasons can be listed as: lack of communication between healthcare personnel and the patient/patient's relative, inadequacy of security measures, excessive working hours for healthcare personnel [15], inability to show sufficient attention to the patient due to an insufficient number of staff, high number of patients, incorrect messages delivered in print, visual, and social media, the death of a patient, dissatisfaction with the treatment, and healthcare personnel experiencing burnout syndrome due to long working hours and working conditions [13,16].

The Legal and Forensic Analysis of Violence in Healthcare (Türkiye)

The right to health, accepted as the right to have the highest possible standard of physical and mental health, is one of the most fundamental rights to life for all people. It is described by the World Health Organization as the right to access and use the facilities and conditions necessary to reach the goal of healthy individuals and society [17]. In Article 25 of the Universal Declaration of Human Rights, the right to health is organized as a guarantee right that everyone should have, stating: “Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing, medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control.” In Article 56 Constitution of The Republic Türkiye, it is regulated that everyone has the right to live in a healthy and balanced environment, and the state has the obligation to ensure that everyone maintains their life in physical and mental health; and to plan and provide services from health institutions through a single hand. The same article also regulates that the state performs this duty by utilizing and auditing health and social institutions in the public and private sectors, and that general health insurance can be established by law to ensure that health services are carried out widely.

Parallel to the technological and scientific developments in recent years, while the expectations from healthcare workers have increased, groups profiting from physician-patient relationships have multiplied, and changes in the health system have brought the concept of patient rights to the forefront, it is observed that the rights of healthcare workers, who are under serious responsibility, are being ignored [8]. Today, although incidents of violence against healthcare workers are increasing, since there is no special legal regulation regarding the responsibilities of healthcare workers, the unfair practices they are exposed to, and violence, cases of violence in healthcare are evaluated according to general regulations [18].

As stated, although there is no separate provision in the Turkish Penal Code to prevent violence in healthcare, some regulations include specific features for healthcare workers. The issues to be evaluated here should be whether the actions taken against the healthcare worker constitute a crime and the punishability

of third parties being deprived of health services as a result of these acts. The Turkish Penal Code No. 5237 regulates certain crimes that we can characterize as violent towards healthcare workers; in terms of our subject, it is possible for crimes such as threat, insult, slander, blackmail, deprivation of liberty, intentional killing, intentional/negligent injury, sexual harassment, sexual assault, damage to property, damage to public property, preventing the benefit of public services, violation of workplace immunity, and resisting to prevent the performance of duty to be committed against healthcare workers. In the healthcare sector, where communication with people is high and two critical issues such as health and the right to life are at the central point, communication problems, insults, threats, injuries, and killing constitute the most common types of crimes we encounter.

Even though there is no separate provision for increasing sentences specifically when these crimes are committed against healthcare workers, for healthcare workers who are public officials, the sentences for crimes of insult, injury, deprivation of liberty, and damage to property are evaluated as "qualified versions" in the relevant law articles, leading to an increase in the penalty amount. In this regard, according to the regulation in the last paragraph of Additional Article 12 of the Basic Law on Türkiye Healthcare Services No. 3359, healthcare workers in private health institutions and organizations are also considered public officials regarding crimes committed in connection with their duties, without any distinction between public or private hospital employees. Thus, the qualified version of the crime will also apply in cases where a healthcare worker in a private health institution is the victim of a crime. The reason for introducing this regulation is that healthcare personnel become victims of violence because they are not sufficiently protected by laws, and healthcare services, which are among the most important services for society, are interrupted. Therefore, the legislator has introduced these regulations for intentionally committed crimes against all healthcare workers, regardless of the private-public sector distinction [19].

Prevention and Management Strategies

While there were no special regulations regarding healthcare workers in the law, with the impact of the pandemic process that affected the entire world, additions were made to Additional Article 12 of the Basic Law on Türkiye Healthcare Services No. 3359 to prevent violence against healthcare workers. It has been ruled that for crimes of intentional injury (Article 86), threat (Article 106), insult (Article 125), and resisting to prevent the performance of duty (Article 265) found in the Turkish Penal Code No. 5237, committed against health personnel and auxiliary health personnel working in both public and private health institutions due to their duties, the penalties to be given shall be increased by half, and the provisions for the postponement of prison sentences regulated in Article 51 of the Türkiye Penal Code shall not be applied.

Furthermore, it is stated in the continuation of the article that if there is another health professional in the institution where the violence occurred who can perform the service provided by the victim, the other personnel will ensure the continuation of the service. Of course, in addition to legal regulations, the determination of healthcare workers to report the violence they experience and the identification and follow-up process of the perpetrator by law enforcement after the crime is committed are very important at the point of preventing the recurrence of crimes.

As a matter of fact, in Additional Article 12 of the Basic Law on Türkiye Healthcare Services, it is regulated that for those suspected of crimes intentionally committed against personnel working in health institutions and organizations due to their duties, the statements of the healthcare personnel to be heard as complainants, victims, and witnesses shall be taken directly at their workplaces, thus providing convenience for healthcare workers and making a regulation for the rapid resolution of the incident.

The existence of violence prevents not only the healthcare workers who are subjected to it but also third parties from benefiting from healthcare services.

Furthermore, in accordance with the Ministry of Health Circular on Employee Safety, a "White Code Unit" has been established to monitor incidents of violence against healthcare workers. It is regulated that anyone subjected to violence can report it to the White Code Unit, and this unit operates 24 hours a day.

When we look at it from the perspective of private law, since the violence experienced constitutes a "tort" (wrongful act), the personnel exposed to violence have the right to file a lawsuit for material and moral damages. Even if the violence occurs as a result of malpractice or the loss of a patient's relative, there is no "legal justification" for the person who carries out the attack on the healthcare worker in this sense.

Discussion

The findings of this study indicate that violence in healthcare should not be viewed solely as an individual or behavioral issue, but rather as a complex and multidimensional problem shaped by systemic, institutional, and socio-cultural factors. Previous studies have consistently identified communication breakdown, excessive workload, and patient dissatisfaction as major contributing factors to violence [4,15,16].

Comparative evidence suggests that healthcare systems with stronger organizational structures and more balanced patient distribution tend to experience lower levels of workplace violence. In many European countries and in the United States, workplace violence is addressed through a combination of preventive strategies, institutional support mechanisms, and workforce planning. These systems often benefit from relatively lower patient-to-provider ratios, stronger primary care structures, and more balanced patient distribution [20,21].

In contrast, the Turkish healthcare system continues to face challenges such as overcrowding, high patient demand, and limited time allocated per patient, which may increase the risk of aggressive behavior [7, 8]. In the United States, studies emphasize the importance of workplace violence prevention programs, staff training, and organizational policies aimed at early identification and de-escalation of violent situations [22]. Similarly, European healthcare systems tend to implement structured preventive measures, including risk assessment protocols and institutional reporting systems [21].

In contrast, the Turkish healthcare system is characterized by high patient demand, overcrowded emergency departments, and limited time allocated per patient. These structural differences may contribute to a higher risk of violence in healthcare settings [7,8].

Furthermore, while many countries emphasize preventive and system-oriented strategies, the approach in Türkiye has been more focused on legal deterrence. This difference suggests that preventive approaches and institutional strategies may be more effective in reducing violence than relying solely on punitive measures [22,23].

This suggests that the limited effectiveness of legal reforms in Türkiye is not solely related to the content of the law, but rather to weaknesses in implementation and enforcement mechanisms. Although recent legal amendments have strengthened penalties, studies indicate that legal measures alone are not sufficient to prevent violence without effective institutional support [18,19].

Another important issue is the role of institutional mechanisms such as the White Code system. Although this system represents an important step toward protecting healthcare workers, its effectiveness remains limited due to the lack of transparency and restricted access to data. This issue has also been discussed in the literature in terms of implementation challenges and legal limitations [9,18].

Furthermore, the findings highlight that systemic factors—such as staff shortages, long working hours, and high patient density—play a critical role in the emergence of violence. Previous studies emphasize that emergency departments, where patient intensity is high, are among the most risky units in terms of violence exposure [8,24].

Therefore, violence in healthcare should be understood not merely as an individual behavioral problem, but as a systemic failure rooted in structural inefficiencies within the healthcare system.

Overall, the results suggest that addressing violence in healthcare requires a comprehensive and integrated approach. In line with previous research, effective solutions should include not only legal regulations but also structural reforms, improved working conditions, and enhanced communication strategies [13,15].

These findings provide a basis for the recommendations presented in the following section.

CONCLUSION

Violence in healthcare remains a critical and persistent challenge that undermines both the efficiency of health systems and the well-being of healthcare professionals, as widely reported in the literature [7,8,13]. The findings of this study demonstrate that, despite recent legal reforms in Türkiye, violence has not decreased proportionally, indicating that legal deterrence alone is insufficient to address the problem [18,19].

This study highlights that violence in healthcare should not be interpreted solely as an issue of individual behavior or criminal intent. Instead, it is a multifactorial phenomenon shaped by systemic deficiencies, institutional practices, and socio-cultural dynamics. High patient density, excessive workload, communication gaps, and unrealistic expectations have been identified as contributing factors in previous studies [4,15,16], collectively creating an environment in which violence becomes more likely.

One of the key contributions of this study is the identification of a critical gap between legal regulation and practical implementation. While healthcare workers are legally recognized as public officials and protected by enhanced penalties, the lack of effective enforcement mechanisms and institutional transparency limits the impact of these regulations. In particular, the restricted accessibility of White Code data prevents comprehensive analysis and evidence-based policymaking, as also discussed in the literature [9,18].

Based on the analytical synthesis of the literature, this study proposes that addressing violence in healthcare requires a holistic and integrated approach. The following strategic recommendations are emphasized:

Enhancing Institutional Transparency

Public access to detailed and anonymized White Code data should be ensured to support scientific research and policy development.

Strengthening Structural Conditions

Reducing patient-to-provider ratios, improving working conditions, and addressing workforce shortages have been emphasized as essential measures in previous studies [13,15].

Improving Communication and Training

Healthcare workers should receive structured training in conflict management and de-escalation techniques, while public awareness campaigns should aim to align patient expectations with medical realities, as suggested in the literature [13,16].

Developing Preventive Policies

Rather than relying solely on punitive legal measures, proactive strategies—such as risk assessment in high-violence units (e.g., emergency departments)—should be implemented, as highlighted in prior research [8,24].

Ensuring Legal and Ethical Balance

Any proposed measures must remain consistent with fundamental human rights, particularly the right to health, and avoid exclusionary practices that may create further inequalities [12,14].

In conclusion, sustainable solutions to violence in healthcare depend on the integration of legal, administrative, and social interventions. Only through a comprehensive reform framework that addresses both the root causes and systemic dimensions of violence can a safer working environment for healthcare professionals—and a more effective healthcare system—be achieved [12,14].

Conflict of interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

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