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Specificity of injuries in child pedestrians of different age categories due to motor vehicle trauma

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Motor vehicle accidents involving child pedestrians remain one of the leading causes of trauma and mortality in the pediatric population. The specific mechanisms of injury formation in child pedestrians require detailed analysis considering age-related anatomical and physiological characteristics.
Aim – to determine the leading mechanisms of injury formation and age-specific patterns of bodily injuries in child pedestrians of different age groups resulting from contact with moving vehicles, in order to provide an evidence base for developing age-differentiated protocols for diagnosis, treatment, and prevention of motor vehicle trauma in the pediatric population.
Materials and methods. A retrospective analysis of forensic medical data, including photoroentgenograms and computed tomography results, was conducted in 87 children aged 2–18 years during 2014–2024. Four age groups were formed: group 1 (2–6 years, n=23), group 2 (7–9 years, n=18), group 3 (10–13 years, n=24), group 4 (14–18 years, n=22).
Results. Males predominated among the victims (63.2%). The highest mortality was recorded in group 4 (18.2%), and the lowest in group 2 (5.6%). The most frequent injuries were traumatic brain injuries (81.6%), lower extremity injuries (55.2%), and upper extremity injuries (54.0%). A statistically significant predominance of abdominal injuries was observed in the youngest children, and thoracic injuries in adolescents.
Conclusions. Statistically significant age-related injury patterns were established: children aged 2–6 years had an increased risk of abdominal injuries, children aged 7–13 years showed predominance of extremity injuries, adolescents aged 14–18 years had the highest mortality and thoracic injuries. These results provide an evidence base for developing age-specific protocols for diagnosis, treatment, and prevention of motor vehicle trauma in children.
The authors declare no conflict of interest.
Keywords: pediatric trauma, motor vehicle accidents, child pedestrians, injury mechanisms, age groups, forensic medical examination.

Специфіка пошкоджень у дітей-пішоходів різних вікових категорій внаслідок автомобільної травми

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Дорожньо-транспортні пригоди з участю дітей-пішоходів залишаються однією з провідних причин травматизму та смертності в педіатричній популяції. Специфічні механізми утворення травм у дітей-пішоходів потребують детального аналізу з урахуванням вікових анатомо-фізіологічних особливостей.
Мета – визначити провідні механізми формування травм та вікові закономірності тілесних ушкоджень у дітей-пішоходів різних вікових груп, отриманих внаслідок контакту з рухомими транспортними засобами, для формування доказової бази розробки диференційованих за віком протоколів діагностики, лікування та профілактики автомобільної травми в педіатричній популяції.
Матеріали та методи. Проведено ретроспективний аналіз судово-медичних даних, зокрема фоторентгенограми та результатів комп'ютерної томографії, 87 дітей віком 2–18 років за період 2014–2024 рр. Сформовано чотири вікові групи: група 1 (2–6 років, n=23), група 2 (7–9 років, n=18), група 3 (10–13 років, n=24), група 4 (14–18 років, n=22).
Результати. Серед постраждалих переважали особи чоловічої статі (63,2%). Найвищу летальність зафіксовано у групі 4 (18,2%), найнижчу – у групі 2 (5,6%). Найчастішими були черепно-мозкові травми (81,6%), травми нижніх (55,2%) та верхніх (54,0%) кінцівок. Статистично значуще переважання абдомінальних травм спостерігалося в наймолодших дітей, торакальних – у підлітків.
Висновки. Встановлено статистично значущі вікові закономірності травмування: діти 2–6 років мали підвищений ризик абдомінальних ушкоджень, діти 7–13 років – переважали травми кінцівок, підлітки 14–18 років – найвищі показники летальності та торакальні ушкодження. Отримані результати формують доказову базу для розробки диференційованих за віком протоколів діагностики, лікування та профілактики автомобільної травми в дітей.
Автори заявляють про відсутність конфлікту інтересів.
Ключові слова: дитячий травматизм, дорожньо-транспортні пригоди, діти-пішоходи, механізми травм, вікові групи, судово-медична експертиза.

Introduction

Pediatric motor vehicle trauma constitutes one of the most significant global health problems of our time. Pedestrian injuries comprise a substantial portion of traumatic morbidity and mortality in children. According to the World Health Organization (2023), more than 1.3 million people die annually in motor vehicle accidents, with children representing a significant proportion of victims [3,8].

Motor vehicle trauma is the leading cause of mortality in children and young people aged 5 to 29 years. Annually, on average, 67,124 child pedestrians are injured, with 704 of them dying [9]. The particular vulnerability of child pedestrians is due to their specific anatomical, physiological, and behavioral characteristics, which fundamentally differ from those of adults [7].

Anatomical features of the child's body include lower body mass, proportionally larger head, which

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Table 1

Distribution of children by age groups

Age group	Age (years)	Number of children	Percentage (%)
Group 1	2–6	23	26.4
Group 2	7–9	18	20.7
Group 3	10–13	24	27.6
Group 4	14–18	22	25.3
Total	2–18	87	100.0

changes the center of gravity, and specific characteristics of skeletal system structure. In children, the presence of epiphyses connected to metaphyses by growth cartilage creates conditions for specific types of injuries [6].

Behavioral characteristics of children significantly increase the risk of motor vehicle injuries. The developmental level of children under 10 years limits their ability to correctly assess vehicle speed, placing them at higher risk of injuries.

Current research demonstrates that despite a decrease in overall pedestrian mortality rates, absolute numbers remain significant. 85% of pedestrian deaths in 2022 occurred in urban areas. An increase in average traffic speed by 1% leads to a 4% increase in the risk of fatal motor vehicle accidents [4].

Forensic medical examination plays a leading role in establishing injury formation mechanisms and their characteristics. Comprehensive analysis of clinical data, radiological diagnostics results, and forensic medical examination allows obtaining a complete picture of traumatic injuries [2].

The aim is to determine the leading mechanisms of injury formation and age-specific patterns of bodily injuries in child pedestrians of different age groups resulting from contact with moving vehicles, in order to provide an evidence base for developing age-differentiated protocols for diagnosis, treatment, and prevention of motor vehicle trauma in the pediatric population.

Materials and methods of the study

A retrospective study was conducted based on forensic medical data, including photoroentgenograms and computed tomography results obtained from inpatient medical records of the Municipal Non-Profit Enterprise «Ivano-Frankivsk Regional Children's Clinical Hospital of IF OR» and during forensic medical examinations of the Ivano-Frankivsk Regional Bureau of Forensic Medical Examination during the period 2014–2024.

The study included pediatric individuals, 87 children aged 2 to 18 years who had pedestrian status at the time of injury. A mandatory condition was confirmation of contact with a moving vehicle. All cases had to have complete medical documentation with a detailed description of the nature and localization of injuries, as well as the availability of radiological diagnostics results, including radiography and computed tomography.

Cases with incomplete medical documentation or the absence of injury mechanism data were excluded from the study. Combined injuries were also not considered. Cases without confirmed contact with a vehicle were excluded.

The obtained data were grouped by age principle (Table 1).

The research methodology included analysis of localization and nature of bodily injuries, assessment of injury severity, determination of types of multiple injuries, establishment of age-related patterns of injury with special attention to radiological diagnostics results.

Statistical processing was performed using the SPSS 26.0 package. Quantitative data with normal distribution are presented as the arithmetic mean and standard error (M±SD). Pearson's χ^2 test was used for comparing categorical variables, and Fisher's exact test when expected frequencies were less than 5. Student's t-test was applied for comparing quantitative indicators. The level of statistical significance was set at $p<0.05$. Bonferroni correction was applied for multiple comparisons.

The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the bioethics committee of Ivano-Frankivsk National Medical University. For patients who were hospitalized, informed consent was obtained from parents/guardians. For forensic medical examination cases, anonymized data were used in accordance with current Ukrainian legislation.

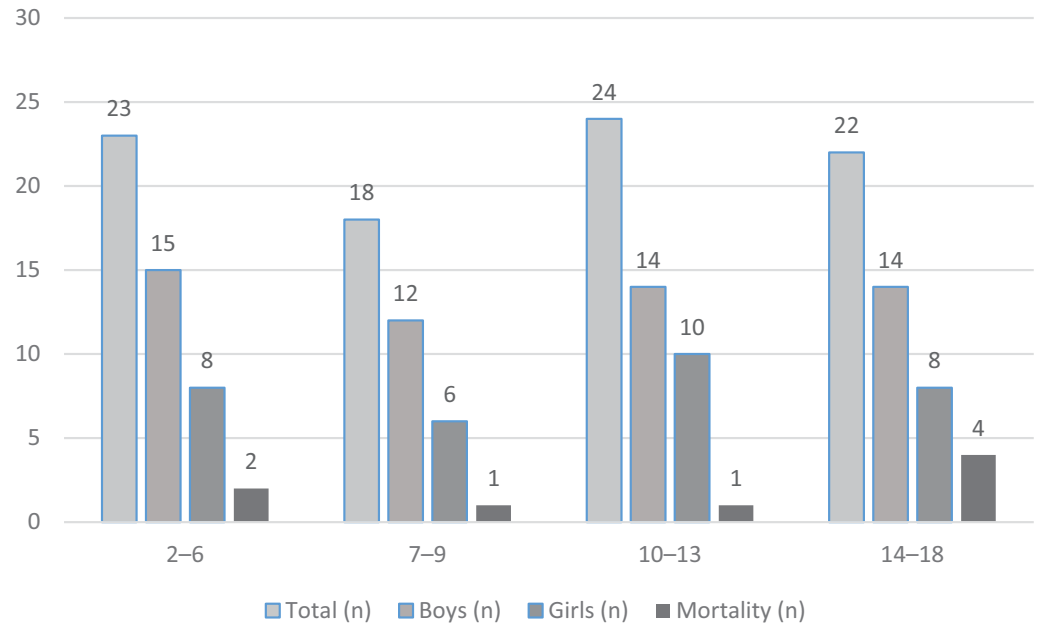

Fig. 1. Demographic characteristics by age groups

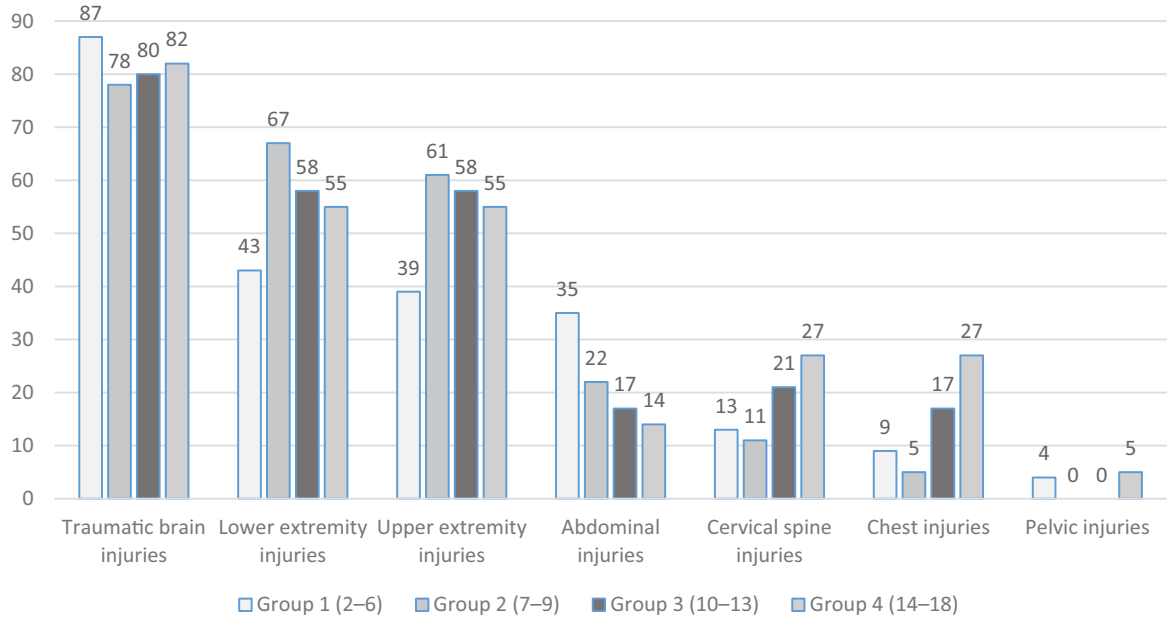

Fig. 2. Localization of injuries in child pedestrians by age groups

Results of the study and discussion

Analysis of demographic characteristics of pedestrians revealed a statistically significant predominance of males – 55 (63.2%) individuals versus 32 (36.8%) females ($p<0.05$). The mean age of the studied cohort was 10.8±4.2 years with a range from 2 to 18 years (Fig. 1).

Mortality analysis revealed statistically significant differences between groups ($p<0.05$). The highest mortality rates were observed in group 4 (14–18 years) – 18.2%, which was statistically significantly different from other groups. The lowest mortality rates were recorded in groups 2 and 3 – 5.6% and 4.2%, respectively.

Analysis of age-related features of injury localization revealed statistically significant patterns (Fig. 2). In group 1 (2–6 years), a statistically significant predominance of abdominal injuries (34.8%) was observed compared to other groups ($p<0.05$), which is explained by the low height of children in this age category and the specific mechanism of primary

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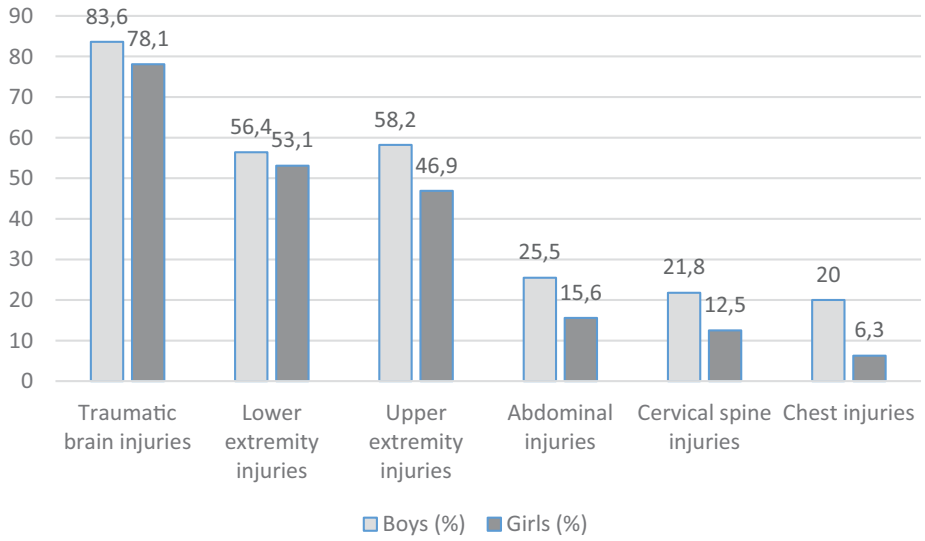

Fig. 3. Gender distribution of injures by injury type

bumper impact at the abdominal level. In group 4 (14–18 years), chest injuries occurred statistically significantly more frequently (27.3%) compared to younger groups ($p<0.05$).

Statistical analysis of gender differences revealed a significant predominance of chest injuries in boys (20.0% vs 6.3%, $p<0.05$), which may be related to differences in behavioral patterns and circumstances of injury (Fig. 3).

The study of injury characteristics revealed a high percentage of multiple injuries – 65 children (74.7%). The highest percentage of multiple injuries was recorded in group 4 (86.4%), the lowest – in group 2 (61.1%), but these differences did not reach statistical significance ($p>0.05$).

Analysis of injury formation mechanisms revealed a clear dependence on anthropometric parameters. Children in group 1 (average height 105.3±8.2 cm) were characterized by a specific injury mechanism with predominance of abdominal injuries. Groups 2 and 3 demonstrated predominance of extremity injuries characteristic of the classic pedestrian injury mechanism. Adolescents in group 4 (average height 169.4±7.3 cm) showed an «adult» type of injury with the highest mortality.

The use of computed tomography proved critically important for complete injury diagnosis, especially in younger children with abdominal injuries and intracranial injuries.

Discussion

The demographic and injury distribution patterns identified in the present study are consistent with data from the international literature. The statistically significant predominance of males among injured child pedestrians (63.2%) reflects a well-documented epidemiological trend. The high frequency of traumatic brain injuries (81.6%) reflects the established vulnerability of the pediatric skull, while the predominance of extremity injuries in groups 2 and 3 is consistent with the classic pedestrian trauma mechanism: in pediatric collisions, the vehicle's front bumper is more likely to strike the upper leg, pelvis, or torso region, pushing the child onto the ground, which differs fundamentally from the adult pattern [1]. The elevated mortality in adolescents aged 14–18 years (18.2%) reflects the transition to an «adult-type» collision dynamic as body proportions and exposure to higher-speed traffic increase with age.

The age-specific injury patterns identified in this study have direct implications for forensic medical practice and clinical management. The statistically significant predominance of abdominal injuries in children aged 2–6 years (34.8%) is explained by anthropometric factors: at a mean height of 105.3±8.2 cm, the vehicle bumper strikes the child at the level of the abdominal cavity rather than the lower extremities. This biomechanical mechanism is recognized in the forensic literature: forensic evaluation of motor vehicle accidents involving children must consider the child's age and the specific dynamics of the collision, which are directly linked to injury localization [9]. The higher frequency of thoracic injuries in adolescents (27.3%) reflects the transition to an adult-type collision mechanism. A systematic review confirms that forensic assess-

ment must account for age-related anatomical differences, and that comprehensive exchange of information between clinicians and forensic specialists is critical for accurate reconstruction of injury mechanisms and development of age-differentiated preventive protocols [9].

Conclusions

The conducted study of injury formation mechanisms and characteristics of bodily injuries in 87 child pedestrians based on a comprehensive analysis of forensic medical data allowed establishing a number of statistically significant patterns. The study confirmed a statistically significant predominance of boys among victims, who comprised 63.2% of the total number of cases in all age groups. The mortality rate demonstrated statistically significant variations depending on age group, with the highest rates observed in adolescents aged 14–18 years at 18.2%.

Data analysis revealed clearly expressed age-specific injury patterns, particularly statistically significant predominance of abdominal injuries in children aged 2–6 years and thoracic injuries in adolescents aged 14–18 years. Special attention should be paid to the high percentage of multiple injuries, which was 74.7%, and justifies the need for implementing a multidisciplinary approach to the diagnosis and treatment of injured children. The study also emphasized the critical importance of computed tomography for complete and accurate assessment of injury characteristics, especially in younger children.

The obtained results create a reliable evidence base for justifying the need to develop age-specific protocols for diagnosis, treatment, and prevention of injuries in child pedestrians, which will improve the effectiveness of medical care and reduce mortality rates in this vulnerable population group.

Prospects for further research. It is advisable to conduct a multicenter study with a larger sample, analyze long-term consequences of injuries, and develop specific diagnostic algorithms depending on age and injury mechanism.

The author declares no conflict of interest.

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