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MODELING ISOLATED FEMORAL FRACTURE AND CONCOMITANT TRAUMA IN NORMAL AND OVERWEIGHT RATS

Hryhoruk V.V., Babenko N.M., Kumetchko M.V., Litvinova O.B.

Kharkiv National Medical University, Kharkiv, Ukraine

Background. The high prevalence of isolated and concomitant lower limb injuries requires reproducible experimental models for studying reparative bone regeneration. Excess body weight substantially alters the pathophysiological response to trauma and complicates the course of the recovery period.

Aim. To develop and justify an experimental methodology for modeling isolated femoral fracture and concomitant trauma with damage to the head, chest and abdominal organs in rats with normal and nutritionally-induced excess body weight.

Materials and Methods. The study was performed within the research project "Implementation of the concept of surgical and orthopedic Damage Control in military and civilian personnel during martial law" (state registration number 01260002120; 2026–2028) on 156 female Wistar Albino Glaxo rats with normal or nutritionally-induced excess body weight (5 groups each). A closed femoral fracture was modeled in 144 animals by retrograde intramedullary osteosynthesis with a 1.0 mm Kirschner wire followed by three-point bending, with radiographic control in two projections. Concomitant injuries were reproduced by a calibrated weight-drop (50 g from a height of 30 cm). Data were analyzed by one-way analysis of variance in SPSS Statistics 26.0 (IBM, USA).

Research Ethics. Experiments were performed in accordance with Directive 2010/63/EU, the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (Strasbourg, 1986) and the Law of Ukraine "On the Protection of Animals from Cruelty". The study design was approved by the Commission on Ethics and Bioethics of Kharkiv National Medical University (Protocol No.8 dated October 17, 2025).

Results. A stable closed transverse femoral fracture was obtained in 98.61% of cases (142 of 144 animals); two rats with an injury of the femoral artery were euthanized and replaced. Intramedullary osteosynthesis provided stable alignment of the fragments while preserving the mobility of the adjacent joints. The calibrated impact reproduced closed injuries of the head, chest and abdominal organs without lethality. In rats with excess body weight, induction of and emergence from anesthesia were prolonged by about 7 min and 17 min, respectively.

Conclusions. The proposed methodology is a reproducible and standardized way of creating models of isolated femoral fracture and concomitant trauma in rats with normal and excess body weight.

Keywords: *orthopedics and traumatology, surgery, traumatic brain injury, thoracic injuries, abdominal injuries.*

Відповідальний автор: Григорук В.В.
✉ 4, пр. Науки, м. Харків, 61022, Україна.
E-mail: vv.hryhoruk@knmu.edu.ua

Corresponding author: Hryhoruk V.V.
✉ 4, Nauky ave., Kharkiv, 61022, Ukraine.
E-mail: vv.hryhoruk@knmu.edu.ua

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Introduction

According to the World Health Organization, approximately 4.4 million deaths worldwide are recorded annually as a result of unintentional or violence-related injuries [1]. Road traffic accidents constitute an especially high proportion, causing approximately 1.3 million deaths each year [2]. In the context of Ukraine, as noted by Guryev S.O. et al. (2025) [3], among civilian victims of hostilities with limb injuries as part of multisystem trauma whose condition was assessed as extremely severe, lower limb injuries accounted for 64.46% of all limb injuries.

The course of the post-traumatic period significantly depends on the patient's baseline metabolic profile. In recent years, a global pandemic of obesity and excess body weight has been observed. The presence of excess adipose tissue induces a state of chronic low-grade inflammation [4] and is associated with impaired microcirculation [5], which may alter the body's systemic response to surgical and mechanical stress. In patients with combined injuries, obesity is associated with a more severe course of traumatic disease and with early and late complications [6].

Thus, to elucidate the systemic and local pathophysiological mechanisms of isolated and concomitant trauma under conditions of normal body weight or metabolic disorders, it is critically important to establish standardized, biologically adequate, and reproducible experimental models in laboratory animals in strict compliance with all international ethical requirements.

The aim of the study was to develop and justify an experimental methodology for modeling isolated femoral fracture and concomitant trauma with damage to the head, chest and abdominal organs in rats with normal and nutritionally-induced excess body weight.

Materials and Methods

The animals were maintained under standard conditions in the vivarium of Kharkiv National Medical University. The study was performed within the research project of Kharkiv National Medical University "Implementation of the concept of surgical and orthopedic Damage Control in military and civilian personnel during martial law" (state registration number 01260002120; 2026–2028). Female Wistar Albino Glaxo (WAG) strain rats aged 9–10 months were used. A total of 156 animals were involved in the study.

Rats with normal weight (n=78): maintained on the standard vivarium diet, with an average body weight of [240±10] g.

Overweight rats (n=78): to replicate dietary-induced metabolic shifts, the animals were maintained on a High-Fat Diet (HFD) enriched with saturated fats and carbohydrates for 4 weeks prior to injury modeling.

HFD consisted of standard rodent chow supplemented with lard (20%), cholesterol (1%), and sucrose (10%), providing 45% of calories from fat, 40% from carbohydrates, and 15% from proteins, with a total energy density of 4.8 kcal/g. The general approach to modeling diet-induced obesity in female rats followed the model described by Giles E.D. et al. (2016) [7]. A 25% increase in body mass relative to age-matched controls (achieving a range of 300–330 g) was used as the validation criterion for excess body weight.

Female rats aged 9–10 months were selected because they represent mature bone structure with stabilized epiphyseal plates, which is essential for replicating adult bone healing. To minimize the confounding effect of

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estrous cycle variation on bone regeneration and pain threshold, all surgical interventions were consistently performed during the diestrus phase, verified by vaginal smear cytology [8].

According to Cao A.B. et al. (2023) [9], the whole-bone bending strength and geometry of the rat femur continue to change from young adulthood to late middle age, which must be taken into account when choosing the age of the animals. The choice of 9–10-month-old animals excludes the confounding influence of active skeletal growth on fracture repair; bone healing in rats of both sexes is additionally modulated by hormonal status, as shown by Komrakova M. et al. (2026) [10]. In mice, Glavas M.M. et al. (2021) [11] demonstrated that the developmental timing of high-fat diet exposure, and not only its duration, determines metabolic outcomes in a sex-specific manner. All 78 rats assigned to the dietary intervention successfully reached the target phenotypic threshold within the 4-week pre-injury period. Following trauma induction, the HFD regimen was sustained continuously throughout the post-traumatic observation window until the scheduled sacrifice intervals (days 7, 14, and 28).

The animals were allocated into 10 experimental groups (8 groups of 18 traumatized animals each (6 animals per sacrifice time point) and two intact control groups of 6 animals each), as shown in *Table*.

Anesthesia was induced by intramuscular injection of tiletamine–zolazepam (Zoletil, Virbac, France) at a dose of 10 mg/kg. For overweight rats, the dose was calculated based on lean body mass estimated at 80% of total body weight to prevent overdose, since zolazepam accumulates in adipose tissue, which can prolong the effect of the drug, as noted by Risi E. et al. (2026) [12]. Surgical depth of anesthesia was monitored by the loss of the pedal withdrawal reflex and corneal reflex.

Modeling of closed femoral fracture with intramedullary osteosynthesis was performed according to a modified technique by De Giacomo A. et al. (2014) [13]. Following surgical field preparation, a minimal approach was performed in the knee joint region. A sterile Kirschner wire with a diameter of 1.0 mm was inserted retrograde through the condylar zone of the right femur into the medullary canal up to the proximal metaphysis. Subsequently, a closed transverse fracture of the middle third of the diaphysis was induced using a specialized three-point bending device [13], which consisted of two lower supports placed at a fixed distance of 15 mm; a blunt guillotine blade weighing 250 g was dropped from a height of 20 cm onto the mid-diaphysis of the femur.

Allocation of animals by groups of traumatized rats

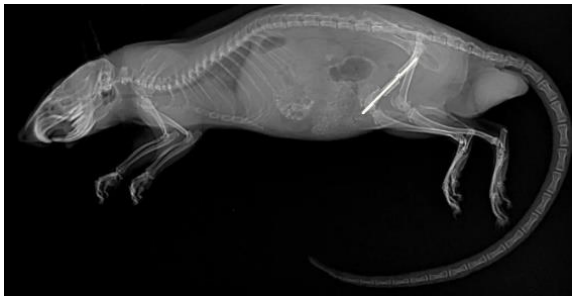
Animal Category / Groups	Group Abbreviation	Type of Injury / Condition	Number of animals (*n*)
Normal body weight (78 rats)			
Intact Control	Int-N	Intact rats	6
Group 1	Fr	Isolated Closed Femoral Fracture	18
Group 2	Fr+CCT	Closed Femoral Fracture and Closed CranioCerebral Trauma	18
Group 3	Fr+BCT	Closed Femoral Fracture and Blunt Chest Trauma	18
Group 4	Fr+BAT	Closed Femoral Fracture and Blunt Abdominal Trauma	18
OverWeight (78 rats)			
Intact Control	Int-OW	Intact OverWeight rats	6
Group 5	OW+Fr	OverWeight and Isolated Closed Femoral Fracture	18
Group 6	OW+Fr+CCT	OverWeight, Closed Femoral Fracture and Closed CranioCerebral Trauma	18
Group 7	OW+Fr+BCT	OverWeight, Closed Femoral Fracture and Blunt Chest Trauma	18
Group 8	OW+Fr+BAT	OverWeight, Closed Femoral Fracture and Blunt Abdominal Trauma	18

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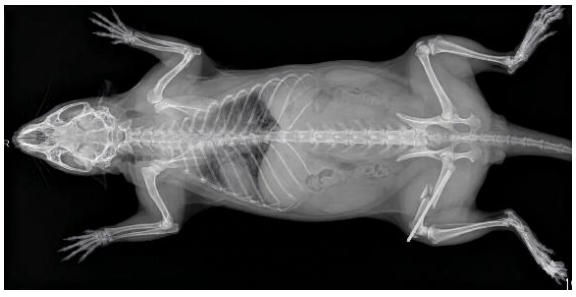
Immediately after the surgery, radiographs were taken in two projections to assess the position of the bone fragments and the intramedullary wire.

Exclusion criteria included comminuted or markedly oblique fractures with significant displacement of bone fragments, as well as hemorrhage from the femoral artery. The stability of the intramedullary fixation and the mobility of adjacent joints were carefully evaluated through gentle palpation of the fracture site and assessment of the passive range of motion in the knee joint. In two rats, a complication – hemorrhage from the femoral artery – occurred during the surgery; these animals were immediately excluded from the study and humanely euthanized, then replaced with other subjects to maintain the sample size.

The position of the wire and the alignment of the fragments are shown in *Fig. 1*.



a – ventrodorsal view, a closed, slightly oblique transverse fracture of the mid-diaphysis of the right femur stabilized by a 1.0 mm Kirschner wire with acceptable alignment of the bone fragments



b – lateral view, intramedullary position of the wire reaching the proximal metaphysis, with fixation of the fracture zone and preservation of the adjacent joint space

Fig. 1. Radiographic control in two projections of a female rat after modeling of a right femoral fracture and retrograde intramedullary osteosynthesis

Postoperative analgesia was provided by subcutaneous administration of meloxicam (2 mg/kg) every 24 h for the first 3 days. Humane endpoints included a loss of more than 15% of body weight, signs of severe respiratory distress, or wound autotomy, but no animals met these criteria. Euthanasia was performed on days 7, 14, and 28 under deep anesthesia via thiopental sodium overdose (60 mg/kg, intramuscularly).

To model concomitant trauma, additional injuries were reproduced immediately after osteosynthesis using a controlled weight-drop of a 50 g load from a height of 30 cm (*Fig. 2*).

Concomitant visceral and tissue injuries were induced immediately following femoral osteosynthesis using a custom-engineered weight-drop system. The mechanical impact parameters – a 50 g cylindrical metal weight falling freely from a fixed height of 30 cm to deliver approximately 0.15 J of kinetic energy – were optimized during preliminary pilot trials. Although the model of Mychasiuk R. et al. (2014) [14] uses a higher energy of about 1.5 J (a 150 g weight dropped from 1.0 m) for an unrestrained head to allow rotational acceleration, our pilot trials demonstrated that applying such energy to a fixed cranium or thoracic cage induced immediate lethality in all animals, secondary to fatal brainstem damage or acute cardiac arrest. To ensure strict standardization of the mechanical impulse, a vertical guide tube 30 cm long with an internal diameter of 15 mm was employed, and a plastic protective disc (10 mm in diameter, 1.5 mm thick) was positioned at the impact site to modulate force distribution. The injury protocols were executed based on anatomical targeting as follows.

Closed CranioCerebral Trauma (Groups Fr+CCT and OW+Fr+CCT): animals were secured on a specialized soft pad in a prone position. The 50 g weight was dropped through the vertical guide tube directly onto the parieto-occipital region of the skull. A critical validation constraint was the strict absence of macroscopic cranial vault fractures, producing an injury phenotype consistent with mild-to-moderate closed Traumatic Brain Injury (TBI).

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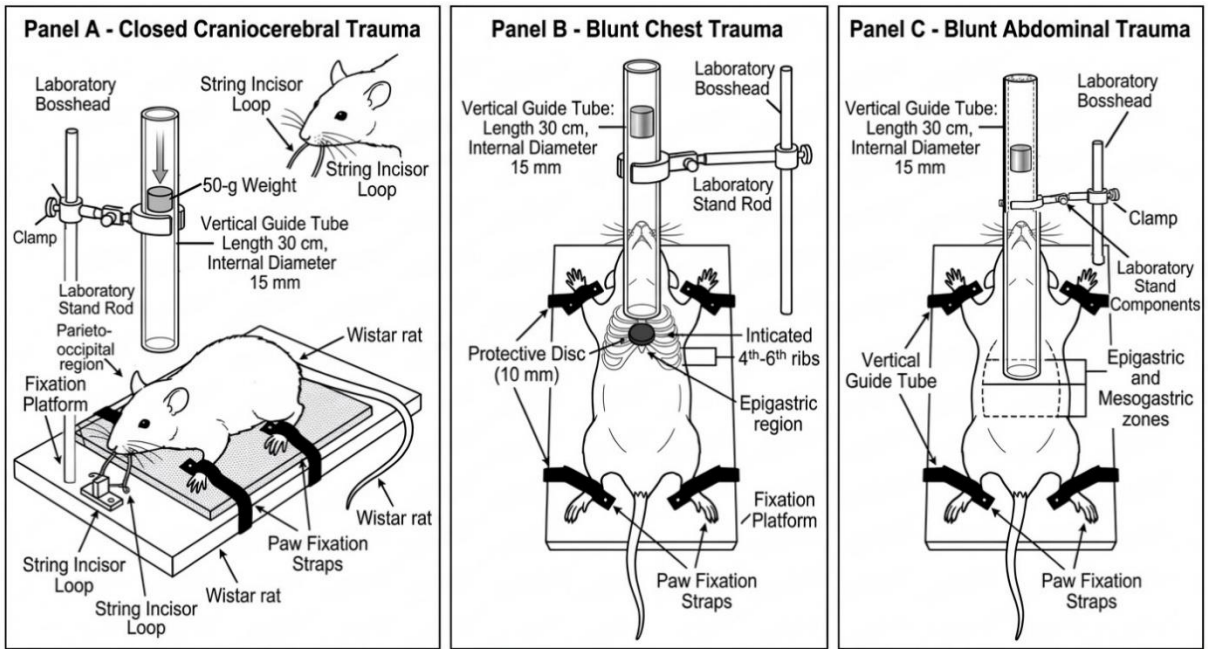


Fig. 2. Modeling of craniocerebral, chest and abdominal trauma: panel A – closed craniocerebral trauma; panel B – blunt chest trauma; panel C – blunt abdominal trauma

The weight-drop principle was adapted from the model of mild TBI in juvenile rats described by Mychasiuk R. et al. (2014) [14]. Modeling of craniocerebral trauma together with blunt abdominal and skeletal trauma in mature rats was also described by Levchuk R. et al. (2026) [15].

Blunt Chest Trauma (Groups Fr+BCT and OW+Fr+BCT): rats were placed in a supine position. The mechanical impact was directed at the anterolateral surface of the thoracic wall, specifically in the projection of the right 4^{th}–6^{th} ribs. The protective disc ensured uniform impulse dissipation, replicating blunt chest trauma with localized pulmonary tissue contusion while avoiding massive rib fractures or chest wall destabilization. In a rat model of polytrauma, Mangum L.H. et al. (2019) [16] showed that blunt chest trauma produced by a falling weight generates standardized lung contusions and can be combined with a femoral injury.

Blunt Abdominal Trauma (Groups Fr+BAT and OW+Fr+BAT): with the animals in a supine position, the controlled weight-drop was applied directly to the anterior abdominal wall, targeting the epigastric and mesogastric zones. This configuration reproduced closed blunt trauma of the parenchymal and hollow internal organs without rupture of the anterior abdominal wall. According to Kafadar H. et al. (2014) [17], blunt abdominal trauma produced in rats by a falling weight most often injures the liver, followed by the spleen and the small intestine.

Statistical analysis was performed in "SPSS Statistics" 26.0 (IBM, USA). Data are presented as Mean ± Standard Deviation ($M \pm SD$). Comparisons between groups were performed using one-way analysis of variance (ANOVA) followed by Tukey's post-hoc test. Differences were considered statistically significant at $p<0.05$.

Research Ethics

Experiments were performed in accordance with the requirements of Directive 2010/63/EU of the European Parliament and of the Council on the protection of animals used for scientific purposes [18], the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (Strasbourg, 1986) [19] and the Law of Ukraine "On the Protection of Animals from Cruelty". The study design was approved by the Commission on Ethics and Bioethics of Kharkiv National Medical University (Protocol No.8 dated October 17, 2025).

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Results

During the experimental work, animal survival rates, osteosynthesis stability, the correctness of injury replication, and the specific features of the early post-operative period course were evaluated across the different groups.

No animal died as a result of the modeled concomitant injuries: no immediate or delayed mortality was recorded in any of the groups with craniocerebral, chest or abdominal trauma up to day 28, which confirms that the calibrated weight-drop impulse does not introduce uncontrolled lethal risks.

As a result of the study, specific modeling features were established in animals with normal weight compared to overweight rats. Notably, when utilizing tiletamine–zolazepam in overweight rats, a prolongation of both anesthesia induction and emergence times was observed compared to animals with normal body weight. This prolongation is hypothesized to be related to the lipophilic nature of tiletamine and zolazepam, leading to potential drug sequestration within the expanded adipose tissue volume, which requires further pharmacokinetic verification.

In overweight rats, the pronounced layer of subcutaneous adipose tissue in the knee joint region required more precise anatomical orientation during retrograde Kirschner wire insertion. However, the use of a wire with a diameter of 1.0 mm provided complete adequacy of the intramedullary fixator both in rats weighing 240 g and in overweight rats weighing 300–330 g.

The three-point bending technique allowed for stable closed transverse femoral fractures in 98.61% of cases (142 out of 144 fractured rats). Two rats (1.39%) sustained a femoral artery injury during the procedure; they were immediately removed from the study, humanely euthanized, and replaced by additional animals to complete the groups.

To differentiate TBI symptoms from general anesthesia, the duration of the righting reflex recovery was measured. Animals in the Fr+CCT and OW+Fr+CCT groups showed a significant delay in restoring the righting reflex ([14.2±1.8] min and [16.5±2.1] min, respectively) compared to the isolated fracture groups under identical anesthesia ([6.4±0.8] min, $p<0.05$). Short-term ataxia and stupor were recorded immediately upon recovery of locomotor activity, confirming a mild-to-moderate brain injury.

In overweight rats, induction time was prolonged to [12.4±1.5] min (vs [5.1±0.6] min in rats with normal body weight, $p<0.01$), and the emergence period was extended to [58.3±6.2] min (vs [41.2±4.5] min, $p<0.05$).

Blunt chest trauma led to a transient increase in respiratory rate to [115±12] breaths/min within the first 2 h (vs [84±8] breaths/min in controls, $p<0.05$). The presence of pulmonary contusions (localized subpleural hemorrhages) was macroscopically confirmed during autopsy on day 7.

For abdominal trauma, minor subcapsular hematomas of the liver or spleen without active parenchymal bleeding were observed during tissue harvesting, verifying the consistency of the mechanical impact method. In the abdominal trauma model, a temporary decrease in locomotor activity, abdominal wall guarding, and a moderate protective body posture were observed during the first 24 h.

Discussion

The results obtained during this experimental work demonstrate the high efficiency, stability, and reproducibility of the developed comprehensive methodology for modeling an isolated femoral fracture and its combination with injuries to various anatomical regions, including TBI, thoracic, and abdominal trauma. Establishing such models is highly relevant for modern traumatology and military medicine, since according to Halvachizadeh S. et al. (2025) [1], trauma remains a leading cause of mortality in the working-age population, and Ahmed S.K. et al. (2023) [2] note that road traffic accidents annually cause 20–50 million non-fatal injuries leading to disability. In the context of Ukraine, as noted by Guryev S.O. et al. (2025) [3], the number of limb injuries among civilians is increasing, and in victims whose condition was assessed as extremely severe, lower limb injuries accounted for 64.46% of all limb injuries.

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The selection of WAG strain rats as the biological model and the modification of classic techniques by De Giacomo A. et al. (2014) [13] and Mychasiuk R. et al. (2014) [14] allowed for strict standardization of the experimental interventions. Intramedullary osteosynthesis with a 1.0 mm Kirschner wire provided stable reduction of bone fragments while preserving adjacent joint mobility. This minimizes the confounding effect of prolonged immobilization on the animal's general condition and allows for the evaluation of the pure pathophysiological impact of the trauma. The successful formation of a stable closed transverse fracture of the mid-diaphysis in 98.61% of cases confirms the technical reliability of the three-point bending device configured according to De Giacomo A. et al. (2014) [13]. Isolated cases of femoral artery injury (n=2) emphasize the necessity of meticulous control over the mechanical force applied during the fracture induction.

The pathogenetic multidirectionality of concomitant mechanical trauma demonstrated in our study agrees with the findings of Levchuk R. et al. (2026) [15], who showed that modeling of craniocerebral, blunt abdominal and skeletal trauma complicated by acute blood loss is accompanied by the development of oxidative stress, which is most pronounced after blunt abdominal trauma. However, their experiments were performed on mature male Wistar rats, and each injury was combined with acute blood loss amounting to 1.5% of body weight, whereas our study addressed a different clinical scenario: the influence of a baseline metabolic disorder in female rats. Our methodology uses a standardized single femoral fracture stabilized by retrograde intramedullary fixation, which allows local tissue healing to be assessed together with visceral injury without the confounding factor of massive systemic hemorrhage. Our data extend these observations by showing that a localized impulse of 0.15 J does not cause immediate lethality, while pre-existing diet-induced excess body weight prolongs the anesthetic window.

Special attention in this study was directed toward the metabolic impact of nutritionally-induced excess body weight achieved via HFD. As documented by Khanna D. et al. (2022) [4], expanded adipose tissue triggers a state of chronic low-grade inflammation, while the review by Scalia R. (2013) [5] underscores significant microvascular dysfunction in obesity, both of which may alter the systemic physiological response to mechanical stress. Our investigations identified distinct features during the early post-operative phase in the overweight cohorts. Specifically, anesthesia induction was delayed by about 7 min and emergence by about 17 min in these animals. This prolongation is hypothesized to be related to the lipophilic nature of tiletamine and zolazepam, leading to potential drug sequestration in the expanded adipose tissue volume [12], which requires further pharmacokinetic verification. This variation highlights the clinical and experimental necessity for a carefully adjusted, individualized anesthetic dosing strategy. Furthermore, the pronounced subcutaneous fat layer obscured conventional anatomical landmarks during retrograde Kirschner wire insertion, requiring heightened surgical precision and careful soft tissue management to prevent intraoperative complications.

The application of a controlled weight-drop (50 g from a height of 30 cm), based on the weight-drop principle of the mild TBI model of Mychasiuk R. et al. (2014) [14], reproduced concomitant injuries without causing immediate lethality. The clinical presentation of mild-to-moderate TBI (delayed recovery of the righting reflex, ataxia), transient tachypnea in thoracic trauma, and abdominal wall guarding in abdominal trauma was consistent with closed injuries of internal organs and tissues.

In clinical practice, obesity aggravates the course of traumatic disease: Khimich S.D. & Chemerys O.M. (2018) [6] reported a more severe course of traumatic disease with early and late complications in obese patients with combined injuries, which substantiates the inclusion of animals with excess body weight in the experimental design.

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Consequently, the proposed allocation into 10 experimental groups enables a detailed assessment of the pathogenic contribution of each concomitant injury under both normal metabolic conditions and nutritionally-induced metabolic disorders, providing a reliable foundation for subsequent morphological and biochemical investigations of bone repair.

Study limitations. Despite the high reproducibility and standardization of the developed methodology, this experimental study has several limitations that should be considered when interpreting the results. The experiment was conducted on rodents (WAG rats), whose anatomical and physiological features of the skeletal system and lipid metabolism differ from those of humans, thereby limiting the direct extrapolation of the findings to clinical practice. The 4-week HFD model induces excess body weight and early metabolic shifts but does not fully replicate the chronic, long-term comorbidities and advanced cardiovascular complications seen in clinical patients with prolonged obesity. The mechanical modeling of concomitant chest and abdominal injuries using the weight-drop method represents closed, controlled trauma, which excludes massive internal hemorrhage, open wounds, and bacterial contamination commonly associated with real-world combat concomitant trauma. A notable limitation of the current experimental design is the omission of sham-operated control groups undergoing anesthesia and surgical exposure without fracture induction. Additionally, the study did not include distinct reference cohorts with isolated traumatic brain injury, isolated blunt chest trauma, or isolated blunt abdominal trauma. Consequently, the specific pathogenic contribution and systemic metabolic input of each concomitant visceral injury can currently be characterized only when superimposed on an existing femoral fracture rather than as independent experimental variables. This structural constraint limits the capacity for direct cross-model comparisons regarding pure tissue-specific responses.

Conclusions

1. The combined application of intramedullary osteosynthesis using a 1.0 mm Kirschner wire and a controlled weight-drop technique (50 g from a height of 30 cm) represents a reproducible and standardized approach for establishing models of isolated femoral fracture and concomitant trauma in rats.

2. The proposed 10-group experimental matrix provides a structured framework for analyzing the cumulative impact of mechanical injuries across different body regions in the presence of standard or altered metabolic status.

3. Modeling mechanical trauma in overweight rats requires careful management of the anesthetic window due to significantly extended induction and emergence phases observed under tiletamine–zolazepam anesthesia.

Declarations

Conflict of interest is absent.

All authors have agreed to the publication of the article under the terms of the Creative Commons BY-NC-SA 4.0 licence and of the public agreement with Kharkiv National Medical University as the founder and publisher of the journal, and to the processing and publication of their personal data.

All stages of the study from the development of the research concept to final editing were conducted entirely by the authors. Generative artificial intelligence tools were used to create the scheme "Modeling of chest, abdominal organs, and craniocerebral trauma" (*Fig. 2*): Gemini 3.8 Flash (Google DeepMind, USA).

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Authors' Contributions

Authors \ Contribution	A	B	C	D	E	F
Hryhoruk V.V.	+	+			+	+
Babenko N.M.		+			+	+
Kumetchko M.V.			+		+	+
Litvinova O.B.				+		+

Notes:

Notes:

A – concept;

B – design;

C – data collection;

D – statistical processing and interpretation of data;

E – writing or critical editing of the article;

F – approval of the final version for publication and agreement to be responsible for all aspects of the work.

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Григорук В.В., Бабенко Н.М., Кумечко М.В., Літвінова О.Б.

МОДЕЛЮВАННЯ ІЗОЛЬОВАНОГО ПЕРЕЛОМУ СТЕГНОВОЇ КІСТКИ ТА ПОЄДНАНОЇ ТРАВМИ У ЩУРІВ ІЗ НОРМАЛЬНОЮ ТА НАДЛИШКОВОЮ МАСОЮ ТІЛА

Актуальність. Висока частота ізольованих і поєднаних травм нижніх кінцівок потребує відтворюваних експериментальних моделей для вивчення репаративної регенерації кістки. Надлишкова маса тіла істотно змінює патофізіологічну відповідь на травму та ускладнює перебіг відновного періоду.

Мета. Розробити та обґрунтувати експериментальну методологію моделювання ізольованого перелому стегнової кістки та поєднаної травми з ушкодженням голови, грудної клітки та органів черевної порожнини у щурів із нормальною та аліментарно-індукованою надлишковою масою тіла.

Матеріали та методи. Дослідження виконано в межах науково-дослідного проєкту «Впровадження концепції хірургічного та ортопедичного Damage Control для військових та цивільних під час воєнного стану» (номер державної реєстрації 01260002120; 2026–2028 рр.) на 156 самицях щурів лінії Wistar Albino Glaxo із нормальною або аліментарно-індукованою надлишковою масою тіла (по 5 груп). Закритий перелом стегнової кістки змодельовано у 144 тварин шляхом ретроградного інтрамедулярного остеосинтезу спицею Кіршнера 1,0 мм з подальшим триточковим згинанням під рентгенологічним контролем у двох проєкціях. Поєднані ушкодження відтворювали дозованим падінням вантажу (50 г з висоти 30 см). Дані опрацьовано однофакторним дисперсійним аналізом у SPSS Statistics 26.0 (IBM, США).

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Етика дослідження. Експерименти виконано відповідно до Директиви 2010/63/EU, Європейської конвенції про захист хребетних тварин, що використовуються для експериментальних та інших наукових цілей (Страсбург, 1986), та Закону України «Про захист тварин від жорстокого поводження». Дизайн дослідження схвалено Комісією з питань етики та біоетики Харківського національного медичного університету (протокол № 8 від 17.10.2025).

Результати. Стабільний закритий поперечний перелом стегнової кістки отримано у 98,61 % випадків (142 зі 144 тварин); двох щурів з ушкодженням стегнової артерії виведено з експерименту й замінено. Інтрамедулярний остеосинтез забезпечив стабільне зіставлення уламків зі збереженням рухливості суміжних суглобів. Дозований ударний вплив відтворив закриті ушкодження голови, грудної клітки та органів черевної порожнини без летальності. У щурів із надлишковою масою тіла введення в наркоз і вихід з нього подовжувалися приблизно на 7 хв і 17 хв відповідно.

Висновки. Запропонована методологія є відтворюваним і стандартизованим способом створення моделей ізольованого перелому стегнової кістки та поєднаної травми у щурів із нормальною та надлишковою масою тіла.

Ключові слова: *ортопедія та травматологія, хірургія, черепно-мозкова травма, ушкодження грудної клітки, ушкодження живота.*

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Information about the authors

Hryhoruk Viktoriia V. – Candidate of Medical Sciences, Docent, Associate Professor of the Department of Emergency and Urgent Medical Care, Orthopedics, Traumatology and Prosthetics; Leading Researcher of the Department of Surgery No.4, Kharkiv National Medical University, Ukraine.

Postal address: 4, Nauky ave., Kharkiv, 61022, Ukraine.
E-mail: vv.hryhoruk@knmu.edu.ua
ORCID: 0000-0002-8937-7802.

Babenko Nataliia M. – PhD in Biology, Leading Researcher of the Department of Surgery No.4, Kharkiv National Medical University, Ukraine.

Postal address: 4, Nauky ave., Kharkiv, 61022, Ukraine.
E-mail: natali_babenko@ukr.net
ORCID: 0000-0003-3117-8146.

Kumetchko Marina V. – Researcher of the Department of Surgery No.4, Kharkiv National Medical University, Ukraine.

Postal address: 4, Nauky ave., Kharkiv, 61022, Ukraine.
E-mail: mv.kumechko@knmu.edu.ua
ORCID: 0000-0002-9153-2461.

Litvinova Olga B. – PhD in Biology, Senior Researcher of the Department of Surgery No.6, Kharkiv National Medical University, Ukraine.

Postal address: 4, Nauky ave., Kharkiv, 61022, Ukraine.
E-mail: o-b-l@i.ua
ORCID: 0000-0002-4558-6979.