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CLINICAL AND LABORATORY PREDICTORS OF POSTOPERATIVE PAIN AFTER ARTHROSCOPIC ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION IN PATIENTS WITH OBESITY

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Background. Anterior Cruciate Ligament (ACL) injury is one of the leading causes of knee instability and reduced functional activity. The results of arthroscopic ACL reconstruction depend largely on the patient's metabolic status.

Aim. To determine the clinical and laboratory characteristics of patients with isolated ACL injury and obesity before arthroscopic reconstruction and to identify factors associated with increased pain intensity at 2 months after surgery in this patient population.

Materials and Methods. This single-center prospective controlled non-randomized study included 90 consecutively enrolled patients with isolated ACL injury of the knee joint who were treated in the Department of Traumatology of the Regional Clinical Hospital, a Municipal Nonprofit Enterprise of the Kharkiv Regional Council, between 2022 and 2024. The groups were formed according to BMI: the main group consisted of 38 patients with obesity (BMI $\geq$30 kg/m²), and the control group included 52 patients without obesity (Body Mass Index (BMI) <30 kg/m²). The following parameters were assessed: Total Cholesterol (TC), Low-Density Lipoproteins (LDL), Very-Low-Density Lipoproteins (VLDL), High-Density Lipoproteins (HDL), TriGlycerides (TG), beta-LipoProteins (β-LP), and the Atherogenic Index (AI). Pain intensity at 2 months after arthroscopic ACL reconstruction was assessed using the Visual Analog Scale (VAS), and associated clinical and laboratory factors were analyzed. Statistical analysis was performed using nonparametric methods and multiple linear regression.

Research Ethics. All patients provided informed consent for participation in the study. The study was conducted in accordance with the Nuremberg Code and the World Medical Association Declaration of Helsinki (1964–2024). The study protocol was approved by the Bioethics Committee of Kharkiv National Medical University (Protocol No 4 of 01.04.2026).

Results. The obesity group had significantly higher levels of TC, LDL, VLDL, TG, β-LP, and AI, as well as lower HDL levels ($p \leq 0.001$). Obesity (β=0.320; p=0.004) and a higher preoperative VAS score (β=0.237; p=0.001) were independently associated with greater pain intensity at 2 months after ACL reconstruction.

Conclusions. The most clinically significant independent predictors of persistent pain at 2 months after arthroscopic ACL reconstruction were obesity and a higher preoperative pain level.

Keywords: *orthopedics and traumatology, anterior cruciate ligament, obesity, postoperative pain, VAS, predictors.*

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Introduction

The knee joint is a hinge joint formed by the femur and tibia. Its static stability is largely ensured by the ligamentous apparatus, among which the Anterior Cruciate Ligament (ACL) plays a key role. The ACL not only prevents anterior translation of the tibia relative to the femur but also provides rotational stability of the knee joint [1; 2].

The functional significance of the ACL is critical, as it plays a central role in stabilizing the knee during flexion, extension, and rotational loading, as well as during complex motor activities such as running and jumping. Consequently, ACL injury is among the most common knee injuries associated with physical activity. Accordingly, ACL reconstruction is one of the most frequently performed arthroscopic orthopedic procedures worldwide [3].

At the same time, epidemiological data indicate a steady increase in the incidence of ACL ruptures, particularly among young individuals and adolescents. Women represent a particularly vulnerable group [4; 5]. The overall age- and sex-adjusted annual incidence of ACL tears is 68.6 per 100,000 person-years. In certain professional or athletic activities, women demonstrate a higher risk of ACL injury compared to men; however, the magnitude of this risk depends on the type and intensity of activity [6].

Although conservative management may be appropriate in selected clinical cases, surgical reconstruction remains the most effective method for restoring knee stability and achieving optimal functional outcomes [7].

However, the effectiveness of surgical treatment depends on multiple factors, among which obesity is one of the most significant. Currently, obesity is recognized as a major global public health issue affecting both adults and children. Patients with obesity more frequently require elective orthopedic procedures and are at increased risk of adverse postoperative outcomes, which is partly attributable to prolonged operative time [8; 9].

In this context, obesity should not be considered merely a comorbid condition. It has a substantial impact on ACL reconstruction, including operative duration, the incidence of early postoperative complications, postoperative physical activity levels, and the risk of subsequent osteoarthritis [10–13]. At the same time, short-term patient-reported outcomes do not always correlate directly with body mass index (BMI) alone, highlighting the need for a broader assessment that includes body composition and functional status [14; 15].

Particular attention should be paid to anthropometric parameters, including the body shape index, which has been identified as an important predictor of knee joint functional outcomes following ACL reconstruction. An increase in this index is significantly associated with a higher risk of impaired knee function, deep vein thrombosis, and ACL graft re-rupture [16].

Thus, a comprehensive assessment of clinical, laboratory, and other parameters, as well as prediction of postoperative complications in patients with obesity, represents an important clinical task for improving outcomes of ACL reconstruction, optimizing surgical strategies, and enhancing rehabilitation protocols. Such an approach enables optimization of both surgical management and postoperative care, as well as reduction in the risk of long-term complications, including post-traumatic osteoarthritis.

The **aim** of the study was to determine the clinical and laboratory characteristics of patients with isolated ACL injury and obesity before arthroscopic reconstruction and to

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identify factors associated with increased pain intensity at 2 months after surgery in this patient population.

Materials and Methods

A single-center prospective controlled non-randomized comparative study was conducted. Patients were enrolled consecutively between 2022 and 2024 according to predefined inclusion and exclusion criteria. Randomization was not performed, since group allocation was based on BMI. The study aimed to evaluate preoperative clinical and laboratory parameters in patients with isolated ACL injury undergoing arthroscopic reconstruction and to assess associations between anamnestic, clinical, laboratory, and treatment-related characteristics and pain intensity at 2 months postoperatively. Pain intensity was assessed using the Visual Analog Scale (VAS), a 10-cm linear scale where 0 indicates no pain and 10 indicates the worst imaginable pain. Patients marked the point on the scale that best corresponded to their perceived pain level, allowing quantitative evaluation of subjective pain.

The following laboratory parameters were assessed: Total Cholesterol (TC), Low-Density Lipoproteins (LDL), Very-Low-Density Lipoproteins (VLDL), High-Density Lipoproteins (HDL), TriGlycerides (TG), beta-LipoProteins (β-LP), and the Atherogenic Index (AI).

Between 2022 and 2024, a total of 90 patients aged 19 to 67 years with isolated ACL injury of the knee joint were examined. All patients were treated in the Department of Traumatology of the Regional Clinical Hospital (Municipal Nonprofit Enterprise of the Kharkiv Regional Council). Patients were divided into two groups according to BMI. The main group included 38 patients with obesity (BMI $\geq$30 kg/m²), whereas the control group included 52 patients without obesity (BMI $<$30 kg/m²). Thus, the groups were formed by consecutive enrollment of eligible patients and subsequent allocation according to the presence or absence of obesity.

All participants were fully informed about the voluntary nature of participation and the confidentiality of collected data prior to enrollment. Inclusion criteria were: age $\geq$18 years; MRI-confirmed isolated ACL injury of the knee joint; planned arthroscopic ACL reconstruction; signed informed consent; and availability for follow-up examination at 2 months after surgery. Exclusion criteria were: combined ligamentous knee injuries; meniscal injuries requiring additional reconstructive procedures; previous surgery on the affected knee; inflammatory arthropathies; rheumatoid arthritis or other systemic connective tissue diseases confirmed according to established clinical criteria; active infectious or inflammatory diseases at the time of surgery; decompensated diabetes mellitus; clinically significant thyroid dysfunction; severe cardiovascular, hepatic, or renal failure; active malignancy; pregnancy or breastfeeding; chronic alcohol dependence; psychiatric disorders limiting adequate pain assessment; and refusal to participate. None of the patients included in the lipid profile analysis received statins, fibrates, ezetimibe, omega-3 fatty acids, or other lipid-lowering therapy during the 3 months preceding surgery.

The mean age of patients in the main group was [36.74±11.14] years, and in the control group, [39.98±11.65] years.

Statistical analysis was performed using SPSS Statistics 25.0 (IBM Corp., USA).

For the main analyzed variables, Shapiro-Wilk and/or Kolmogorov-Smirnov tests indicated significant deviations from normal distribution: TC, LDL, VLDL, HDL, TG, β-LP, AI, preoperative VAS, and VAS at 2 months showed $p<0.05$ in at least one normality test. Since most lipid profile parameters and VAS scores showed significant deviations from normal distribution according to at least one of the normality tests ($p<0.05$), nonparametric statistical methods were applied. Data were presented as Median (Me) and interquartile range [Q1–Q3], where Q1 represents the 25th percentile and Q3 the 75th percentile.

Associations between studied variables and the dependent continuous variable were evaluated using multiple linear regression analysis with calculation of regression coefficients, 95% Confidence Intervals (CI), and coefficient of determination (R^2).

The regression analysis was performed in several stages. First, a baseline model including

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obesity status and preoperative VAS score was constructed. These variables were retained in all subsequent models because of their clinical relevance. Second, additional variables were entered by clinically defined blocks: medico-social characteristics, physical examination parameters, treatment-related variables, lipid profile parameters, glucose and coagulation parameters, and complete blood count parameters. Additional variables were assessed in separate block models. Variables with p<0.10 in intermediate models and/or clinically meaningful associations were considered for inclusion in the final multivariable model. Lipid profile parameters were analyzed separately because of potential intercorrelation among lipid fractions. The final model was interpreted with emphasis on variables that retained statistical significance after multivariable adjustment.

Differences between two independent groups were assessed using the Mann–Whitney U test. A p-value <0.05 was considered statistically significant.

Research Ethics

All participants were included in the study after providing informed consent. The study was conducted in full accordance with international and national bioethical standards, including the Nuremberg Code and the World Medical Association Declaration of Helsinki (1964–2024). Ethical approval was obtained from the Bioethics Committee of Kharkiv National Medical University (Protocol No 4 of 01.04.2026).

Results

The obtained results (*Table*) demonstrated that the lipid profile showed the most pronounced and consistent intergroup differences. Specifically, the level of total cholesterol (TC) in the non-obese group was 4.68 [4.54–4.80] mmol/L, whereas in the obese group it was 5.15 [5.06–5.30] mmol/L (p<0.001).

Elevated TC levels in the context of traumatic injury and surgical intervention may be considered a component of systemic metabolic dysregulation, which may potentially influence reparative processes and adaptation to mechanical loading.

In turn, LDL levels were significantly higher in the obesity group than in the non-obesity group (p<0.001), measuring 2.91 [2.58–2.99] mmol/L versus 2.61 [2.54–2.69] mmol/L, respectively. This increase is of clear clinical relevance because LDL is the principal atherogenic fraction of the lipid profile. In patients with obesity, higher LDL levels reflect more pronounced dyslipidemia and indicate a systemic metabolic milieu that may adversely affect microcirculation, vascular reactivity, and overall tissue trophism, thereby directly influencing reparative processes after arthroscopic reconstruction.

Table. Distribution of patients with isolated ACL injury according to lipid profile parameters, Me [Q1–Q3]

Parameters	Obesity		p
	no (n=52)	yes (n=38)	
TC, mmol/L	4.68 [4.54–4.80]	5.15 [5.06–5.30]	<0.001
LDL, mmol/L	2.61 [2.54–2.69]	2.91 [2.58–2.99]	<0.001
VLDL, mmol/L	0.72 [0.64–0.83]	1.07 [1.00–1.33]	<0.001
HDL, mmol/L	1.32 [1.28–1.35]	1.17 [1.13–1.21]	<0.001
TG, mmol/L	1.60 [1.43–1.81]	2.31 [2.15–2.58]	<0.001
β-LP, mmol/L	57.40 [55.95–59.20]	68.90 [61.78–70.80]	0.001
AI	2.57 [2.36–2.75]	3.39 [3.18–3.63]	<0.001

Notes: statistical significance of differences between patients with isolated ACL injury of the knee joint without obesity and those with obesity;
TC – Total Cholesterol;
LDL – Low-Density Lipoproteins;
VLDL – Very-Low-Density Lipoproteins;
HDL – High-Density Lipoproteins;
TG – TriGlycerides;
β-LP – beta-LipoProteins;
AI – Atherogenic Index.

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VLDL levels were 0.72 [0.64–0.83] mmol/L in the non-obesity group and 1.07 [1.00–1.33] mmol/L in the obesity group ($p<0.001$). In orthopedic trauma patients, this finding indicates more pronounced metabolic impairment, which may potentially affect the rate of functional recovery and overall quality of life.

Conversely, HDL levels were significantly lower in patients with obesity: 1.17 [1.13–1.21] mmol/L versus 1.32 [1.28–1.35] mmol/L in the non-obesity group ($p<0.001$), indicating reduced antiatherogenic potential of the blood plasma. Thus, the obesity group demonstrated not only elevated atherogenic fractions but also a simultaneous reduction in the protective fraction, consistent with an overall unfavorable systemic metabolic profile.

TriGlyceride (TG) levels were also significantly lower in the non-obesity group, at 1.60 [1.43–1.81] mmol/L, whereas in the obesity group they were 2.31 [2.15–2.58] mmol/L ($p<0.001$). Elevated TG levels in the obesity group suggested features of underlying metabolic syndrome and indicated that, in the studied patients, obesity was associated not only with mechanical overload of the joint but also with systemic metabolic disturbances that may adversely affect reparative processes, physical endurance, and subjective well-being.

β-lipoprotein levels were also significantly higher in the obesity group: 68.90 [61.78–70.80] versus 57.40 [55.95–59.20] ($p=0.001$), confirming the atherogenic orientation of the lipid profile in patients with obesity and potentially increasing the risk of vascular and trophic disturbances after surgery.

The AI was significantly lower in the non-obesity group, at 2.57 [2.36–2.75], compared with 3.39 [3.18–3.63] in the obesity group ($p<0.001$), confirming the presence of systemic atherogenic dyslipidemia in patients with obesity and indicating a possible predisposition to postoperative complications and broader somatic risks.

When factors associated with pain intensity according to the VAS at 2 months after arthroscopic ACL reconstruction were assessed, postoperative pain was found to be significantly associated with two principal factors: the presence of obesity and baseline preoperative pain severity. Specifically, obesity was an independent positive predictor of higher pain intensity ($\beta=0.320$; CI [0.104–0.536]; $p=0.004$), while a higher preoperative VAS score was likewise associated with greater pain intensity at 2 months after surgery ($\beta=0.237$; CI [0.096–0.379]; $p=0.001$).

Further expansion of the model by adding medico-social characteristics did not alter the overall pattern of the identified associations. Obesity remained statistically significant ($\beta=0.323$; CI [0.104–0.542]; $p=0.004$), and baseline pain also remained a significant predictor ($\beta=0.249$; CI [0.107–0.391]; $p=0.001$). In contrast, sex ($\beta=-0.108$; CI [-0.312 to 0.096]; $p=0.294$), age ($\beta=0.006$; CI [-0.003 to 0.014]; $p=0.199$), elective hospitalization ($\beta=-0.008$; CI [-0.233 to 0.217]; $p=0.943$), and length of hospital stay ($\beta=0.005$; CI [-0.026 to 0.036]; $p=0.739$) showed no statistically significant association with postoperative pain intensity.

A similar pattern was observed after inclusion of physical examination parameters. Obesity remained a significant predictor of increased pain intensity ($\beta=0.329$; CI [0.108–0.550]; $p=0.004$), and preoperative VAS remained an independent factor associated with persistent pain ($\beta=0.232$; CI [0.091–0.372]; $p=0.002$). Systolic blood pressure showed only a trend toward association with pain ($\beta=0.017$; CI [-0.003 to 0.036]; $p=0.090$), whereas diastolic blood pressure ($\beta=0.005$; CI [-0.017 to 0.027]; $p=0.647$) and heart rate ($\beta=-0.008$; CI [-0.040 to 0.025]; $p=0.642$) had no statistically significant effect. These findings suggest that, at this stage of postoperative recovery, hemodynamic parameters no longer determine pain intensity to the same extent as baseline pain burden and metabolic characteristics.

After the addition of treatment-related variables, the leading roles of obesity ($\beta=0.351$; CI [0.134–0.569]; $p=0.002$) and baseline pain severity ($\beta=0.259$; CI [0.117–0.401]; $p<0.001$) were again confirmed. Among therapeutic factors, anticoagulant therapy in a separate model was associated with lower pain intensity at 2 months after arthroscopy ($\beta=-0.333$; CI [-0.650 to -0.017]; $p=0.039$).

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In contrast, the prescription of analgesics (β=0.120; CI [-0.496 to 0.736]; $p=0.699$) and antibacterial agents (β=-0.141; CI [-0.398 to 0.115]; $p=0.277$) showed no statistically significant association. The variable "compresses/dressings" was not included in the analysis because these procedures were prescribed to all patients.

The inclusion of individual laboratory parameters also did not change the overall configuration of the model. When blood glucose level was added, obesity remained statistically significant (β=0.319; CI [0.102–0.536]; $p=0.004$), as did preoperative VAS (β=0.237; CI [0.095–0.379]; $p=0.001$), whereas preoperative blood glucose was not a significant predictor of pain at 2 months after arthroscopy (β=0.018; CI [-0.080 to 0.115]; $p=0.722$). A similar pattern was observed after adding a coagulation parameter: obesity (β=0.317; CI [0.098–0.535]; $p=0.005$) and preoperative VAS (β=0.235; CI [0.093–0.378]; $p=0.002$) remained significant, whereas the International Normalized Ratio (INR) had no independent statistically significant effect (β=-0.141; CI [-1.060 to 0.778]; $p=0.761$).

Particular interest was drawn to the analysis of lipid profile parameters, which were assessed separately in a series of multivariable models because of intercorrelation among them. This approach was used to determine which specific component of the lipid profile was most strongly associated with postoperative pain intensity. Total cholesterol (β=-0.001; CI [-0.140 to 0.138]; $p=0.987$), LDL (β=0.008; CI [-0.131 to 0.146]; $p=0.914$), VLDL (β=-0.048; CI [-0.163 to 0.067]; $p=0.408$), HDL (β=0.094; CI [-0.176 to 0.363]; $p=0.491$), β-lipoproteins (β=0.001; CI [-0.007 to 0.007]; $p=0.969$), and AI (β=0.091; CI [-0.068 to 0.249]; $p=0.258$) did not show a statistically significant association with pain at 2 months after surgery. In contrast, TG level was associated with higher pain intensity in an individual exploratory model (β=0.130; 95% CI [0.003–0.257]; $p=0.045$), and the corresponding model demonstrated an explanatory value of $R^2=0.350$. In that model, obesity also remained statistically significant (β=0.235; 95% CI [0.008–0.463]; $p=0.043$), while preoperative VAS remained independently associated with postoperative pain intensity (β=0.200; 95% CI [0.056–0.343]; $p=0.007$). However, since the association between TG and postoperative pain did not remain statistically significant in the final multivariable model, this finding should be interpreted as exploratory and requiring further validation.

A similar approach was applied to complete blood count parameters. Most variables were not significantly associated with postoperative pain intensity. In separate exploratory models, leukocyte count showed an inverse association with pain (β=-0.054; 95% CI [-0.105 to -0.003]; $p=0.037$; $R^2=0.353$), and basophils were also inversely associated with pain intensity (β=-0.470; 95% CI [-0.870 to -0.069]; $p=0.022$; $R^2=0.359$). Eosinophils showed a similar trend (β=-0.061; 95% CI [-0.124 to 0.003]; $p=0.060$; $R^2=0.346$). However, these associations did not remain statistically significant in the final multivariable model. Therefore, leukocytes and basophils should not be interpreted as confirmed independent predictors, but only as exploratory variables whose potential role requires further investigation.

At the final stage, an integrated multivariable model was constructed to assess the combined contribution of the principal clinical and laboratory factors to pain intensity at 2 months after arthroscopy. The explanatory power of the model was 45.9% ($R^2=0.459$). The model included obesity, preoperative VAS pain score, anticoagulant therapy, TG level, leukocyte count, eosinophils, and basophils.

Only obesity (β=0.333; 95% CI [0.108–0.559]; $p=0.004$) and preoperative VAS pain score (β=0.218; 95% CI [0.082–0.355]; $p=0.002$) remained statistically significant independent factors in the final model. Anticoagulant therapy ($p=0.086$), TG level ($p=0.058$), leukocyte count ($p=0.055$), eosinophils ($p=0.082$), and basophils ($p=0.115$) demonstrated borderline or non-significant associations. Therefore, these variables were not interpreted as confirmed independent predictors, but only as exploratory factors requiring further validation.

The results of all intermediate regression models (medico-social, physical examination, treatment-related, lipid profile, and complete

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blood count) are presented in the corresponding paragraphs above. For each model, the regression coefficient (β), 95% confidence interval, p-value, and coefficient of determination (R^2) are provided. None of the additional variables included in the intermediate models demonstrated a statistically significant independent association with pain intensity at 2 months after surgery, confirming the robustness of the main findings regarding obesity and baseline pain severity.

Thus, the obtained results indicate that, at 8 weeks after surgery, pain intensity is more strongly associated with stable biological characteristics of the patient than with situational or hospitalization-related factors. This is most clearly reflected in the persistent independent effects of obesity and baseline pain severity. These data suggest that patients with obesity are more likely to experience persistence of more intense pain even in the later postoperative period.

It should be noted that, according to our findings, achieving a sustained analgesic effect after ACL reconstruction in patients with obesity requires more than technically successful surgery alone. A comprehensive approach appears warranted, including preoperative risk stratification, assessment of metabolic profile, and consideration of patient-specific clinical characteristics. Such a strategy may improve longer-term treatment outcomes, optimize rehabilitation, and reduce the risk of persistent pain.

Discussion

Our findings indicate that obesity in patients with isolated ACL injury reflects a systemic metabolic phenotype that, already at the preoperative stage, is associated with atherogenic dyslipidemia and subsequently influences the persistence of pain after reconstruction. In our study, patients with obesity had higher levels of TC (5.15 [5.06–5.30] vs 4.68 [4.54–4.80] mmol/L; p<0.001), LDL (2.91 [2.58–2.99] vs 2.61 [2.54–2.69] mmol/L; p<0.001), VLDL (1.07 [1.00–1.33] vs 0.72 [0.64–0.83] mmol/L; p<0.001), TG (2.31 [2.15–2.58] vs 1.60 [1.43–1.81] mmol/L; p<0.001), β-lipoproteins (68.90 [61.78–70.80] vs 57.40 [55.95–59.20]; p=0.001), and AI (3.39 [3.18–3.63] vs 2.57 [2.36–2.75]; p<0.001), as well as lower HDL levels (1.17 [1.13–1.21] vs 1.32 [1.28–1.35] mmol/L; p<0.001). At the same time, only obesity (β=0.333; 95.0% CI [0.108–0.559]; p=0.004) and preoperative VAS score (β=0.218; 95.0% CI [0.082–0.355]; p=0.002) remained statistically significant independent factors in the final multivariable model. TG level was associated with pain only in an individual exploratory model and did not retain statistical significance after multivariable adjustment. These findings are consistent with current studies showing that excess body weight worsens the course of ACL reconstruction, although the mechanism of this effect is not uniformly expressed across all endpoints. In the analysis by Fang Z. & Liu W. (2024) [11], obesity after ACL reconstruction was independently associated with longer hospitalization and a higher likelihood of nonroutine discharge, although it did not increase the rate of immediate postoperative complications in the NIS database. These findings suggest that obesity exerts a stronger effect on overall clinical course and healthcare resource utilization than on major early surgical events. Our results further refine this concept by demonstrating that one of the most sensitive clinical consequences during the first 8 weeks is pain persistence [11].

Our results are consistent with the findings of Fang Z. & Liu W. (2024) [11], who demonstrated that obesity after ACL reconstruction was associated with a longer hospital stay and a higher likelihood of nonroutine discharge, although it did not significantly increase the rate of immediate postoperative complications. In our study, obesity was independently associated with greater pain intensity at 2 months after surgery, which suggests that the adverse effect of obesity may be reflected not only in healthcare resource utilization but also in early patient-reported postoperative outcomes. The findings of Lustig M.A. et al. (2024) [14] indicate that BMI within the range of [15–30] kg/m² does not necessarily influence patient-reported outcomes after ACL reconstruction. This partially differs from our results, which may be explained by

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the fact that our obesity group included patients with BMI ≥30 kg/m² and demonstrated a more pronounced atherogenic lipid profile. Therefore, our data support the view that the clinical relevance of obesity after ACL reconstruction may depend not only on BMI itself but also on the associated metabolic phenotype. The nationwide cohort study by Byun J. et al. (2024) [12] showed that increasing BMI was associated with a higher risk of subsequent surgical treatment for osteoarthritis and meniscal lesions after ACL reconstruction, although obesity did not increase the revision ACL reconstruction rate. These findings complement our results, since greater early postoperative pain in patients with obesity may reflect a broader unfavorable biomechanical and metabolic background that may also contribute to worse long-term knee outcomes. Our findings are also in line with Wang Y.J. et al. (2023) [16], who reported that body shape index was associated with functional prognosis after ACL reconstruction, including worse knee function and a higher risk of deep vein thrombosis. This supports the interpretation that obesity should not be considered only as excess body weight. Fat distribution, metabolic activity, microcirculatory changes, and laboratory markers may also contribute to postoperative recovery. Unlike most previous studies, which focused primarily on BMI, body composition, or functional outcomes, our study additionally assessed lipid profile parameters. TG was associated with postoperative pain only in an individual exploratory model and did not remain statistically significant in the final multivariable model. Therefore, this result should be interpreted cautiously and considered hypothesis-generating rather than confirmatory.

A similar rationale is supported by the study by Lim S. et al. (2023) [10], in which body weight and BMI were directly correlated with operative time during arthroscopic ACL reconstruction; the group with longer operative duration had body weight greater by 14.7 kg and BMI higher by 4.5 kg/m², while a body weight threshold >74.25 kg was associated with a probability of surgery lasting more than 61 minutes. Because prolonged operative time is regarded as a risk factor for complications, these findings are also consistent with our results demonstrating an unfavorable effect of obesity on the early postoperative course.

It should also be noted that in the study by Lustig M.A. et al. (2024) [14], BMI in the range of [15–30] kg/m² did not have a significant effect on patient-reported outcomes after ACL reconstruction using a 10-mm bone–patellar tendon–bone graft, indicating that BMI alone is not always sufficient to predict subjective outcomes, especially in populations without marked obesity and under more homogeneous surgical conditions. Our findings similarly suggest that in obesity, clinical risk is likely mediated not solely by BMI but by the combination of obesity with metabolic dysregulation, particularly hypertriglyceridemia.

The systematic review by Ninkovic S. et al. (2023) [13] also demonstrated a negative association between higher BMI and physical activity after reconstruction; specifically, BMI >25 kg/m² was associated with lower levels of subjectively assessed physical activity. These findings are comparable with our observation of a less favorable early postoperative condition in patients with obesity, as lower physical activity and poorer tolerance to exertion may be associated with prolonged pain persistence, delayed rehabilitation, and reduced functional adaptation.

Studies evaluating the association of obesity not only with early pain but also with longer-term structural knee damage after ACL reconstruction should also be highlighted. In the 2024 nationwide study by Byun J. et al. (2024) [12], obesity did not increase the rate of revision ACL reconstruction; however, with increasing BMI, the likelihood of additional surgical treatment for osteoarthritis and meniscal injuries increased significantly. In patients with obesity, the risk of additional intervention for meniscal pathology was HR 1.10 (95.0% CI [1.01–1.21]; p=0.0351). These findings complement our results by suggesting that early postoperative pain in patients with obesity may serve as one clinical marker of a broader biomechanical and metabolic adverse background that may subsequently contribute to degenerative progression.

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Additional support for this interpretation is provided by studies addressing biomechanical outcomes in patients with ACL injury and obesity. Garcia S.A. et al. (2024) [17] reported that patients with high BMI after ACL reconstruction exhibited more adverse indicators of articular cartilage loading and altered cartilage functional properties, including approximately 10.0% greater changes in medial trochlear echostiffness compared with patients with normal BMI. This further underscores the significance of our findings regarding the effect of obesity on ACL reconstruction outcomes, according to which pain, functional recovery, and the risk of post-traumatic osteoarthritis may all be interrelated with obesity.

The TG-related finding should be interpreted with caution. In the present study, TG was the only lipid profile parameter associated with postoperative pain intensity in an individual exploratory model. However, this association did not remain statistically significant in the final multivariable model after adjustment for obesity, preoperative pain severity, treatment-related factors, and complete blood count parameters. Therefore, TG cannot be regarded as an established independent prognostic marker based on the present data. Rather, it may represent a hypothesis-generating laboratory parameter reflecting the metabolic phenotype of patients with obesity and requires further investigation in larger independent cohorts.

Our results are also consistent with the study by Wang Y.J. et al. (2023) [16], according to which an abdominally oriented body shape index was associated with worse knee function, lower return to functional activity, and a higher risk of deep vein thrombosis after ACL reconstruction. This supports our conclusion that obesity should be considered more broadly than as a BMI value alone; fat distribution, metabolic activity, and microcirculatory mechanisms likely have independent clinical significance [16].

Thus, our findings are consistent with other contemporary studies and indicate that, as early as 2 months after arthroscopic ACL reconstruction, pain intensity is associated not only with obesity per se and baseline VAS score, but also, potentially, with selected features of the metabolic profile. This supports preoperative risk stratification based not only on BMI but also on laboratory and clinical factors.

Limitations

The present study has several limitations. First, this was a single-center non-randomized study with group allocation based on BMI, which may be associated with selection bias. Second, the relatively limited sample size restricts the number of variables that can be reliably included in multivariable regression models and may increase the risk of model overfitting. Third, some associations identified in intermediate models, including those involving TG, leukocytes, basophils, and anticoagulant therapy, did not remain statistically significant in the final model and should therefore be interpreted as exploratory. Fourth, the follow-up period was limited to 2 months, which allows assessment of early postoperative pain but not long-term functional outcomes.

Conclusions

Thus, in determining the clinical and laboratory characteristics of patients with isolated ACL injury and obesity prior to arthroscopic reconstruction and identifying predictors of increased postoperative pain intensity in this patient population, the following conclusions were drawn.

1. Patients with isolated ACL injury and obesity had a significantly more unfavorable lipid profile prior to arthroscopic reconstruction compared with patients without obesity ($p \le 0.001$).

2. Obesity and higher preoperative VAS pain score were independent predictors of greater pain intensity at 2 months after arthroscopic ACL reconstruction.

3. Among laboratory parameters, only TG level showed a statistically significant association with higher postoperative pain in an individual model; however, this association did not remain significant in the final multivariable model.

4. The final multivariable model demonstrated an explanatory power of 45.9% ($R^2=0.459$), with obesity and baseline pain severity being the only statistically significant independent factors.

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Declarations

Conflict of interest is absent.

The author has given consent to the publication of the article under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License and a public agreement with the publisher, to the processing and publication of their personal data. The author of the manuscript states that in the process of conducting research, preparing, and editing this manuscript, no generative AI tools or services were used to perform any of the tasks listed in the Generative AI Delegation Taxonomy (GAIDeT, 2025). All stages of work (from the development of the research concept to the final editing) were carried out without the involvement of generative artificial intelligence, exclusively by the author.

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Дрокін А.В.

КЛІНІКО-ЛАБОРАТОРНІ ПРЕДИКТОРИ ПІСЛЯОПЕРАЦІЙНОГО БОЛЮ ПІСЛЯ АРТРОСКОПІЧНОЇ РЕКОНСТРУКЦІЇ ПЕРЕДНЬОЇ ХРЕСТОПОДІБНОЇ ЗВ'ЯЗКИ У ПАЦІЄНТІВ З ОЖИРІННЯМ

Актуальність. Ушкодження передньої хрестоподібної зв'язки (ПХЗ) є однією з провідних причин нестабільності колінного суглоба та зниження функціональної активності. Результати реконструкції ПХЗ значною мірою залежать від метаболічного статусу пацієнта.

Мета. Визначити клініко-лабораторні характеристики пацієнтів з ізольованим ушкодженням ПХЗ та ожирінням перед артроскопічною реконструкцією та встановити фактори, асоційовані з підвищеною інтенсивністю болю через 2 місяці після оперативного втручання.

Матеріали та методи. Проведено одноцентрове проспективне контрольоване нерандомізоване дослідження 90 послідовно включених пацієнтів з ізольованим ушкодженням ПХЗ колінного суглоба, пролікованих у 2022–2024 рр. у травматологічному відділенні Комунального некомерційного підприємства Харківської обласної ради «Обласна клінічна лікарня». Групи формували за показником індексу маси тіла (ІМТ): основну групу становили 38 пацієнтів з ожирінням (ІМТ ≥30 кг/м²), контрольну – 52 пацієнти без ожиріння (ІМТ <30 кг/м²). Рандомізацію не проводили, оскільки розподіл пацієнтів визначався наявністю або відсутністю ожиріння. Оцінювали значення загального холестерину (ЗХ), ліпопротеїнів низької (ЛПНЩ), дуже низької (ЛПДНЩ) і високої (ЛПВЩ) щільності,

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тригліцеридів (ТГ), β ліпопротеїнів (β-ЛП), коефіцієнту атерогенності (КА) та визначали фактори, асоційовані з інтенсивністю болю через 2 місяці після артроскопічної реконструкції ПХЗ за візуально-аналоговою шкалою (ВАШ). Статистичний аналіз виконано з використанням непараметричних методів та множинної лінійної регресії.

Етика дослідження. Усі пацієнти надали інформовану згоду на участь у дослідженні. Роботу виконано відповідно до положень Нюрнберзького кодексу та Гельсінської декларації. Дослідження схвалене комісією з біоетики Харківського національного медичного університету.

Результати. У групі з ожирінням встановлено достовірно вищі показники ЗХ, ЛПНЩ, ЛПДНЩ, ТГ, β-ЛП і КА та нижчий рівень ЛПВЩ ($p \le 0{,}001$). Ожиріння ($\beta=0{,}320$; $p=0{,}004$) та вищий доопераційний рівень болю за ВАШ ($\beta=0{,}237$; $p=0{,}001$) були незалежно асоційовані з вищою інтенсивністю болю через 2 місяці після реконструкції ПХЗ.

Висновки. Найбільш клінічно значущими факторами, незалежно асоційованими з болем через 2 місяці після артроскопічної реконструкції ПХЗ, були ожиріння та вищий доопераційний рівень болю.

Ключові слова: *ортопедія та травматологія, метаболічний профіль, передня хрестоподібна зв’язка, ожиріння, післяопераційний біль, ВАШ, предиктори.*

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