The impact of war on people with type 2 diabetes in Ukraine: a survey study

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Summary

Background Although the number of studies reporting war-induced effects on the health of the Ukrainian population has been growing, there are still little data on assessing patients with type 2 diabetes (T2D) during the war. This study aimed to evaluate the impact of war on T2D patients' health to define key risk factors promoting disease progression.

Methods A survey covering various aspects of T2D patients' experience and glycemic control data was conducted from June 2022 to February 2024. Overall, 1193 patients from all regions of Ukraine were enrolled in the study. According to the difference between the initial and current levels of HbA1c, all the respondents were subdivided into two categories: progressors (with HbA1c levels greater than 5% of the initial value) and stable (patients with stable HbA1c levels). Next, the impact of intrinsic and war-related factors on T2D progression was assessed via logistic regression analysis and machine learning tools.

Findings Two years of war experience was associated with significant increase in the median HbA1c from 7.8% (7.0–8.93) to 8.4% (7.4–9.9; $p < 0.001$), with the highest value occurring in eastern and northern Ukraine. HbA1c levels demonstrated a time-dependent pattern of growth, reflecting the cumulative effect of war-related factors on T2D patients' health. Witnesses of armed attacks and occupation aggravated the T2D course. Experience with military actions ($p = 0.002$), occupation ($p = 0.001$), internal displacement ($p = 0.018$) and family member injury or death ($p = 0.031$) increased HbA1c. In addition, lack of regular glucose monitoring ($p < 0.001$), consultation by endocrinologists ($p < 0.001$), diet inconsistency ($p = 0.017$) and scarcity of physical activity ($p = 0.047$) affected the HbA1c parameters.

Interpretation This study demonstrated a dramatic cumulative effect of the war on T2D patients' health. Uncovered direct and indirect war-related risk factors can guide further adjustment of diabetic care in Ukraine to improve T2D patient support.

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Keywords: Type 2 diabetes; War; Humanitarian crisis; Displacement; Disaster; Chronic stress

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Research in context

Evidence before this study

We carried out a search through MEDLINE (Ovid) and Embase (Ovid) for studies using the following terms: ("diabetes" or "type 2 diabetes") and ("war" or "war in Ukraine" or "refugees" or "displacement"). Only papers published in the English language were considered. We found one manuscript addressing the barriers to diabetic care during the war in Ukraine and one paper uncovering diabetic foot care during the war. The authors of both publications addressed the challenges in the healthcare system and the need for adequate care to improve outcomes of people living with diabetes.

Added value of this study

It was one of the first studies globally, analyzing the effect of war on health outcomes of patients with T2D. Based on survey covering all the regions of Ukraine, we obtained the first evidence of the impact of the war on health of people living with diabetes, shedding light on the most significant intrinsic and war-related factors affecting HbA1c levels. This is the first study demonstrating the cumulative effect of the war on the T2D course, which undermines glycemic control maintenance, threatens health and outcomes of persons with diabetes. War-related experience, occupation or displacement together with the inability to monitor glucose, maintain diet and physical activity, and get endocrinologist support were the most significant factors in worsening the T2D course. These results define patients at greater risk of T2D progression and can inform planning prevention measures and further improvements in diabetic care.

Implications of all the available evidence

The data obtained through this study depict the most vulnerable groups of patients living with diabetes in Ukraine who are at the greatest risk of worsening diabetes course and further complication development. Uncovered risk factors related to the direct war experience are essential for developing robust action plans to help patients with diabetes by safeguarding the affordability of healthcare and empowering individuals with diabetes to control the disease and prevent its progression.

Introduction

The ongoing war in Ukraine heavily affected the healthcare system and the physical and mental health of various vulnerable populations. According to the UN Refugee Agency, as of February 2024, approximately 14.6 million Ukrainian people needed humanitarian assistance.[1] One-third of the Ukrainian population was displaced by the war: nearly 6.5 million refugees have been recorded globally, and nearly 3.7 million Ukrainians have been internally displaced, resulting in vulnerable populations that are sensitive to structural injustice and associated health problems.[1] Despite significant advances in transforming the healthcare system in Ukraine, there is still inequitable access to healthcare services and medications. The russian invasion in Ukraine has further disrupted medical services, including diabetes care.[2] Hospitals and civil objects are destroyed through missile strikes, and healthcare units are forced underground for safety, aggravating the challenges in healthcare availability, access and affordability. These obstacles include the lack of timely intervention, diagnostic procedures and laboratory testing with postponed access to diabetes care, which can cause serious long-term health consequences.

Previous reports have demonstrated the impact of the war on cervical screening, perinatal medicine, cancer care and mental health in Ukraine.[3–7] Although the number of studies reporting war-induced effects on the Ukrainian civil population, internally displaced persons and refugees has been growing, there are still little data on the health of people living with type 2 diabetes (T2D) during the war. Notably, approximately 7.1% of the adult population in Ukraine is suffering from T2D. War as a humanitarian disaster affects various aspects of diabetic care, including direct military threats, distress associated with being displaced and becoming refugees, the accessibility of healthcare facilities and clinicians, the affordability of proper measures for health control, diet and lifestyle issues, which are essential for maintaining metabolic parameters in individuals with T2D.

Thus, this study aimed to evaluate the impact of war on health of persons living with diabetes to define key risk factors promoting T2D progression.

Methods

Ethics

The study protocol was approved by the Ethics Committee at Bogomolets National Medical University (protocol No 160; from 29.09.2022). The purpose and methodology of this cross-sectional study were disclosed to the participants before data collection. Patients who consented to participate in the study completed questionnaires together with endocrinologists (Appendix pp. 2–8).

Study design

According to the project's goal, a survey was conducted. The survey included the following domains: 1) demographic data; 2) disease history before the war; 3) T2D parameters at the time of the survey; 4) geographic allocation of the respondents; and 5) experience facing various factors of the war. The electronic survey was posted on social media and distributed among endocrinologists working in different regions of Ukraine for further dissemination at inpatient and outpatient healthcare institutions. The survey was completed once per participant at a single time point.

The inclusion criteria were as follows: T2D, aged 20–75 years, and access to electronic devices. Persons with T1D and nondiabetic individuals were excluded from the study. The responses were gathered during the period from June 2022 to February 2024, covering almost two years of the ongoing war. We invited 1400 people to compete the survey. The response rate of survey was 85.2%. For complete case analysis overall 1193 patients were enrolled in the study, including 590 men and 603 women (Table 1). Among the 1193 respondents, approximately one-third were from western Ukraine (353; 29.6%), 283 (23.7%) were from northern Ukraine (including Kyiv), 260 (21.9%) were from the central part of Ukraine, and 196 (16.4%) and 101 (8.5%) were from eastern and southern Ukraine, respectively.

Methodology of the study

In the first step of this cross-sectional study, we assessed the data on war-related factors faced by the responders. The general impact of the war on glycemic control was evaluated, by applying HbA1c levels reported by participants at the time of the survey. We also considered the incidence of T2D individuals with HbA1c over the 7.5% and 10% thresholds, representing patients with poor glycemic control.

The responses were collected from June 2022 to February 2024, covering 7 time periods of 3 months each (Appendix Table S1). As 3-month timing corresponds to the rate of erythrocytes turnover, it can also reflect the impact of chronological events on the dynamics of HbA1c levels. Using these abovementioned endpoints, we assessed the glycemic control parameters of T2D persons during various periods of the war with respect to sex, age, and geography.

To evaluate the impact of various factors on maintenance of glycemic control, we considered initial (before the war) and current (at the time of the survey) levels of HbA1c and calculated the difference between these parameters (delta). The full data at this step were available for the sample of 933 responders. According to the amplitude of the HbA1c shift, we subdivided all respondents into two groups: progressors (who demonstrated that HbA1c levels increased over 5% compared with the initial values) and stable (persons with stable HbA1c levels). This approach was applied to assess the impact of various factors on patients' health by regression analysis and ML-based modeling.

For further prognostication, anthropometric data (age, sex, weight, height, BMI), T2D duration, region of residence, experience of direct military threats, occupation, forced displacement and its duration, family loss or injuries, glucose monitoring, affordability of endocrinologist support, hypoglycemia episodes, diet and physician activity maintenance during the war were considered.

Variables	Parameters
Total number of participants	1193 (100%)
Males	590 (49.5%)
Females	603 (50.5%)
Age, years, Me (IQR) [Range]	62 (54–69) [22–93]
Under 60 years	539 (45.2%)
Over 60 years	654 (54.8%)
Weight, kg, Me (IQR) [Range]	87 (78.0–90.2) [50–196]
Height, cm, Me (IQR) [Range]	170 (164–176) [147–200]
BMI, kg/m^2, Me (IQR) [Range]	30.6 (26.6–36.5) [18–54]
Diabetes duration, years, Me (IQR) [Range]	8 (4–14) [0–38]
Residence (region of Ukraine)	1193 (100%)
Central	260 (21.8%)
Western	353 (29.6%)
Eastern	196 (16.4%)
Southern	101 (8.5%)
Northern	283 (23.7%)

Table 1: **Demographic characteristics of the study participants.**

Statistical analysis and machine learning models for identifying prognostic factors

Statistical analysis was performed using MedCalc® Statistical Software version 22.026 (MedCalc Software Ltd., Ostend, Belgium; https://www.medcalc.org; 2024). Given the non-Gaussian character of the variable distribution, nonparametric criteria were applied. The continuous variables (age and HbA1c levels) are presented as the median (Me) and interquartile range (IQR) or 95% confidence interval (95% CI). The Kruskal–Wallis or Mann–Whitney test was used to compare the independent data. To compare the paired samples, the Wilcoxon signed rank test was used.

Logistic regression analysis and machine learning (ML) algorithms were applied to define the factors impacting the outcome in progressors. The age, BMI, and HbA1c variables were considered continuous, and age was ranked into categories according to the WHO classification. BMI ranks included categories <30 and >30. Diabetes duration was defined as newly diagnosed, 1–5 years, 6–15 years, and >15 years. Occupation and military attack witnesses were considered dichotomic variables (YES or NO). Occupation duration was ranked as no occupation experience, up to 15 days, 16–30 days, or >30 days. Displacement was categorized as internal or external. We also considered family separation when family members were relocated but the respondent stayed at the living place. The geography of residence included the western, eastern, northern, southern and central regions of Ukraine. The consistency of glucose self-monitoring, support from endocrinologists, diet and physical activity were also included in the analysis.

Using logistic regression, we evaluated the impact of war (factor X) on health of people with diabetes to define key risk factors promoting T2D progression (Y). Both X and Y were considered as binary variables. The sample size of $n = 930$ was requested for detecting the average effect ($OR = 1.5$) under $Pr(Y = 1|X = 1) = 0.5$, probability of type I error $\alpha = 0.05$ and Power = 80%.[8]

To construct the multivariate logistic regression model, stepwise analysis was applied (the inclusion criterion was $p < 0.1$, and the exclusion criterion was $p > 0.2$). To estimate the efficiency of the logistic regression models, the area under the ROC curve (AUC) and its 95% CI were calculated. To estimate the effects of risk factors on the dependent variable, odds ratios (ORs) and 95% CIs were calculated. A p value < 0.05 was considered significant.

The open-source H2O.ai autoML library for Python[9] was employed to train and cross-validate a variety of ML algorithms, including gradient boosting machine (GBM), extreme gradient boosting, general linear models, extremely randomized trees, distributed random forest, and deep learning. The default setup and parameters in the H2O.ai package were used in the study. Before model training, continuous variables were normalized via quantile transformation. Subsequently, autoML was utilized to train 50 models with 10-fold cross-validation, evaluating and ranking them on the basis of their AUC. For the top model, we calculated permutation importance, Shapley additive explanations (SHAPs) and plotted partial dependence to illustrate feature effects.

Role of the funding source

The funder of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

Results

The impact of the war on glycemic control in T2D patients

A comparison of HbA1c levels before the war and during the survey demonstrated a significant worsening of glycemic control in responders. While the initial HbA1c level was 7.8 (7.0–8.9), the median level of HbA1c during the war reached 8.4 (7.4–9.9; $p < 0.001$) (Table 2). As a result, the percentage of patients with HbA1c > 7.5% also increased significantly throughout the period of observation ($p < 0.001$). Similarly, the share of patients with HbA1c levels over 10% doubled, shifting from 11.6% before the war to 24.1% at the time of the survey.

The cumulative effect of the war on T2D patients' health

HbA1c levels demonstrated a time-dependent pattern of growth throughout the survey period, reflecting the cumulative effect of war-related factors on T2D peoples' health (Fig. 1A). The most significant increase in HbA1c levels was reported in period 3, corresponding to the Winter of 2023, which was the time after massive attacks on energetic infrastructure and blackouts.

Similarly, the percentage of patients with poor glycemic control (over 7.5%) also increased over the observation period (Fig. 1B). In Period 1, the percentage was 66.4% and slightly elevated in Period 2 to 66.9%, whereas in Period 3, the percentage of individuals with poor glycemic control reached 76.8%, increasing to 82.4% in Period 6 (autumn 2023). The same trend was observed for the incidence of HbA1c over 10% (Fig. 1C).

The sex-specific and age-related distributions of HbA1c in different study periods are presented in Fig. 2A and B. Starting from period 2, we found that women were more vulnerable to the impact of war-related factors than men were. However, in the last half a year, we observed the smoothing of the situation (Fig. 2A). Another finding was that younger people under 60 years with T2D were more vulnerable than those who were older than 60 years. Moreover, a significant difference between the mean HbA1c values in periods 3 and 5 was detected (Fig. 2B).

These data reflect the cumulative effect of war-related factors on T2D persons' health, demonstrating the upward trend for worsening of glycose metabolism and accumulation in patients with decompensated T2D.

Region-specific differences in T2D patients' glycemic control during wartime

A comparison of HbA1c levels among patients from different geographic zones revealed significant differences in glycemic control, with the lowest values in the western population compared with the other Ukrainian patients (Appendix Table S2), whereas the most significant increase in HbA1c was detected in responders from northern and eastern Ukraine.

Nevertheless, all regions of Ukraine demonstrated a continuous increase in HbA1c levels, with the sharpest growth among the patients from the eastern part of Ukraine, accompanied by an increased number of patients with poor glycemic control requiring advanced therapy (Fig. 2C).

War-related traumatic experience: the role of direct aggression in worsening T2D patients' glycemic control

Witnesses of war and occupation aggravated the T2D course (Appendix Table S2). Among the observed cohort, 266 (28.5%) patients faced direct military threats, including missile attacks, shootings, and war-related deaths or injuries. All of them were from areas occupied by Russian troops. Seventy of the 266 patients (7.5%) experienced short-term occupation for up to 15 days, 85 (9.1%) of the responders faced occupation for up to 1 month, and 111 (11.9%) were in occupied territories for 2 months or more. Experience with active military actions (p = 0.002) and occupation more than one month (p = 0.001) were associated with increased HbA1c levels. Fig. 2D presents the dynamics of HbA1c in a quarterly manner between responders who were directly affected and those who were not affected by war.

Displacement also droves the worsening of glycemic control. About one-third of the respondents 318 (34,1%) out of 933 reported long-term forced displacement within Ukraine or abroad due to safety reasons. Of those 318 individuals, 299 (32%) were internally displaced and 19 (2%) were refugees in another country. Moreover, 63 (6.8%) from internally displaced persons stayed in Ukraine separated from their family being relocated abroad. Besides 255 (27.3%) of respondents faced short-term relocation within Ukraine with further returning home after the acute phase of military aggression in their region. Notably, that in univariate logistic regression analysis internal displacement as opposite to refuges (p = 0.018) and long-term vs short-term displacement (p = 0.041) significantly affected HbA1c levels (Table 3).

More than a quarter of the respondents (243 out of 933 respondents, 26%) experienced relatives or close friends being injured or killed during the war. This type of trauma also contributed to increases in HbA1c levels (p = 0.031).

In addition to direct threats of the war, most responders reported difficulties in maintaining basic requirements related to disease monitoring and lifestyle. Of the 933 respondents, 24% (n = 220) reported irregular glucose monitoring, and 13% (n = 123) lacked documented glucose measurements. Hospitalizations due to hyperglycemic exacerbations were reported by 48% (n = 450) of participants. Moreover, 24% (n = 223) reported hypoglycemia, with 25% of these cases involving severe hypoglycemia, defined as requiring assistance from another person. Moreover, there were difficulties in receiving endocrinologist consultation in 198 (21.2%) patients, with only online communication in the other 128 (13.7%) patients. In addition, 593 patients (63.6%) reported diet alterations, and 565 (60.6%) respondents noted a scarcity of proper physical activity. Lack of regular glucose monitoring (p < 0.001), consultation by endocrinologists (p < 0.001), diet inconsistency (p = 0.017) and deficits in physical activity (p = 0.047) affected HbA1c parameters the most significantly.

Factors	HbA1c before the war Me (Q_I–Q_{III})	HbA1c at the moment of the survey Me (Q_I–Q_{III})	p_1	Relative Delt, Me [95% CI],%	p_2
All responders	7.8 (7.0–8.9)	8.4 (7.4–9.9)	<0.001	6.3 [5.3–7.2]	
Gender					
Men	7.9 (7.0–8.7)	8.3 (7.4–9.7)	<0.001	5.7 [4.7–7.0]	0.164[a]
Women	7.8 (7.0–9.0)	8.5 (7.3–10.0)	<0.001	6.7 [5.1–8.8]	
Age					
Under 44 (n = 68)	7.5 (6.8–8.3)	8.2 (7.5–9.3)	<0.001	9.6 [4.5–12.7]	0.686[b]
45–60 (n = 346)	7.9 (7.0–9.0)	8.6 (7.5–10.1)	<0.001	4.9 [4.2–8.2]	
61–75 (n = 448)	7.8 (7.0–8.9)	8.4 (7.3–9.8)	<0.001	6.2 [4.7–8.5]	
>75 (n = 91)	7.8 (7.0–8.8)	8.2 (7.5–9.6)	<0.001	6.0 [4.6–8.6]	
BMI					
<30 (n = 455)	7.8 (7.0–8.7)	8.2 (7.4–9.7)	<0.001	5.7 [4.9–6.7]	0.474[b]
≥30 (n = 476)	7.9 (7.0–9.0)	8.6 (7.4–10.0)	<0.001	6.6 [5.1–8.8]	
Diabetes duration					
Newly diagnosed (n = 73)	7.4 (6.4–8.7)	8.0 (6.8–10.1)	<0.001	12.5 [5.1–17.9]	0.078[b]
1–5 (n = 260)	7.3 (6.7–8.3)	7.6 (7.0–9.0)	<0.001	5.7 [3.8–7.6]	
6–15 (n = 407)	8.0 (7.2–8.9)	8.7 (7.6–9.8)	<0.001	6.7 [5.1–8.9]	
>15 (n = 191)	8.3 (7.1–9.5)	8.9 (7.6–10.0)	<0.001	5.3 [3.6–7.1]	

Notes: p_1—comparison of the HbA1c before the war vs HbA1c at the moment of a survey by the Wilcoxon signed rank test for paired samples. p_2—comparison of the HbA1c increase (Relative Delt = ($HbA1c_{after}$ – $HbA1c_{before}$)/$HbA1c_{before}$*100%) by the: [a]—Mann–Whitney test, [b]—Kruskal–Wallis test. Me—median.

Table 2: **Changes in HbA1c levels before and during the war in Ukraine with respect to intrinsic factors.**

Deciphering the most impactful factors affecting diabetes progression during the war

Worsening of the T2D course was detected in more than half of the respondents. A total of 508 (54.4%) out of 953

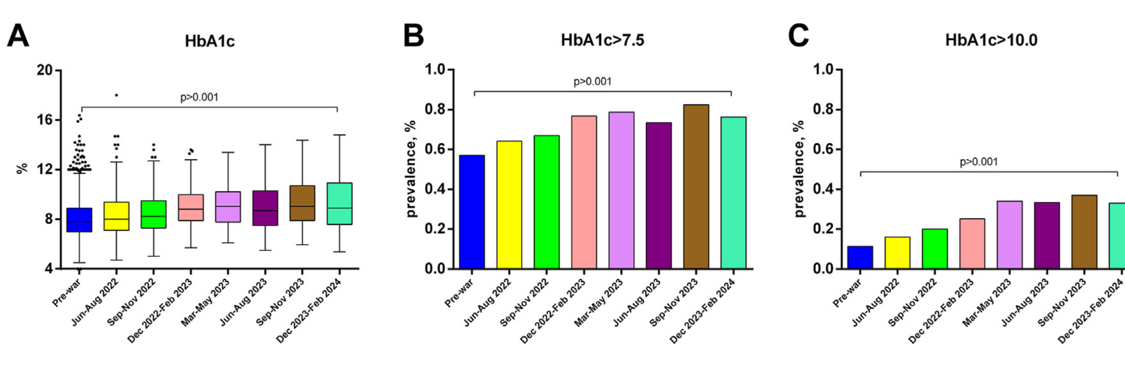

Fig. 1: The dynamics of HbA1c levels at different periods of the war (according to the survey responses). A—The HbA1c levels at different periods of the observation. B and C—represent the percentages of patients with HbA1c levels ≥7.5% and 10%, respectively.

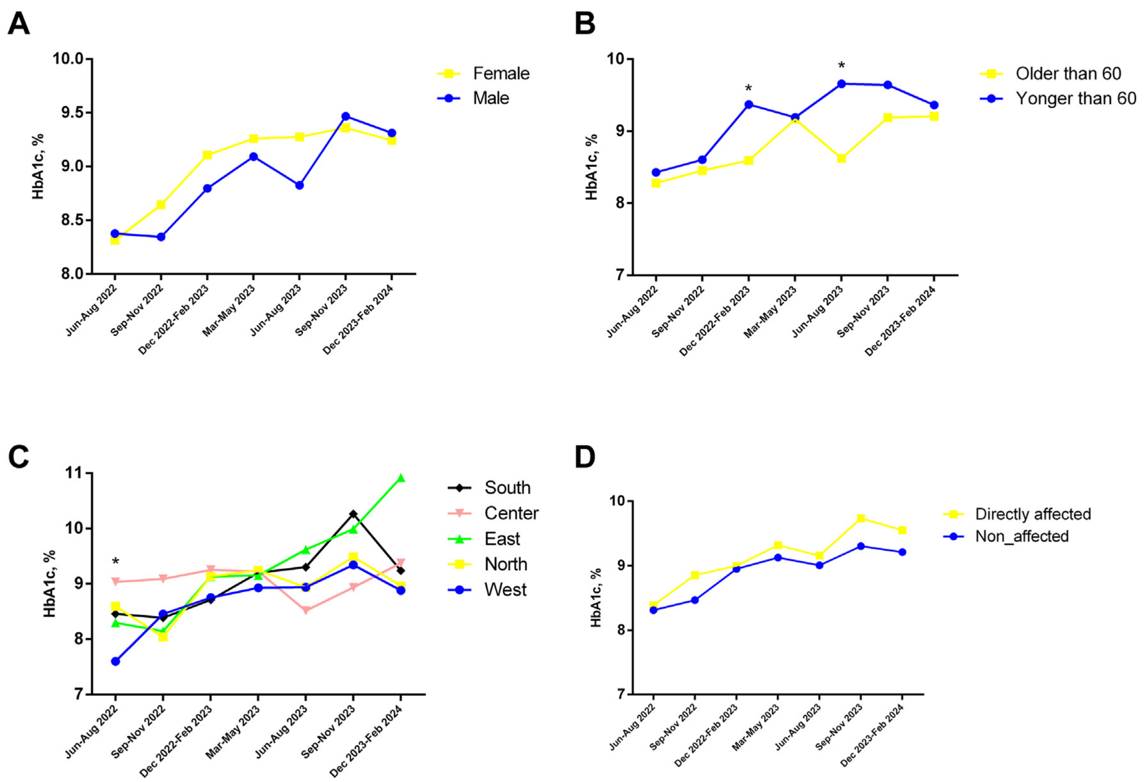

Fig. 2: Differences in HbA1c dynamics among responders during the war depending on sex (A), age (B), geographic zone of Ukraine (C) and war-related traumatic experience (D). *–indicates significant difference between parameters in current timepoint.

patients demonstrated an increase in HbA1c of more than 5% compared with the initial level. When intrinsic parameters were assessed, univariate logistic regression analysis revealed the role of the initial level of HbA1c ($p < 0.001$). Surprisingly, lower HbA1c values indicated more profound worsening of glycemic control.

Most war-related factors, including direct military attacks ($p = 0.001$), occupation ($p = 0.002$), displacement within Ukraine ($p = 0.018$) and relatives' injury or death ($p = 0.031$), as well as the duration of war exposure ($p < 0.001$), were correlated with T2D progression. Geographic location, which assumes exposure to different dangers, also clearly distinguishes between the eastern and northern regions, underscoring the impact of being close to the front line and targeted by strikes regularly.

In addition, nonavailability of endocrinologist support ($p = 0.001$), lack ($p < 0.001$) or irregular ($p = 0.008$) glycemic monitoring, altered diet ($p = 0.017$) and inappropriate physical activity ($p = 0.047$) were also correlated with T2D progression (Table 3).

Multivariable logistic regression modeling revealed four main factors impacting T2D progression, they included the initial level of HbA1c, duration of war-related factor exposure, occupation longer than 1 month, and lack of regular glucose monitoring (Table 3). The constructed model was adequate (chi-square value of 112.4, $p < 0.001$), with an AUC of 0.69 (95% CI 0.66–0.72), demonstrating the satisfactory impact of the defined factors on the risk of T2D progression (Appendix Fig. S1). When the threshold value of the model was selected according to the Youden index (criterion>0.464), the sensitivity was 85.4% (95% CI 82.1%–88.4%), and the specificity reached 45.4% (95% CI 40.6%–50.3%).

Similar data were obtained when ML-based algorithms were used. Among the models tested, the GBM model was the most effective, achieving an AUC of 0.69 in the validation set. The application of ML-based algorithms revealed the most powerful effects on initial HbA1c levels, BMI (and weight), patient age, duration of exposure to war-related factors, T2D duration and glucose monitoring, as well as regional and war-related experiences (occupation, family affected and displacement) (Fig. 3). Although the logistic regression and ML-based models demonstrated modest performance, they underscored the most impactful warning-related factors affecting health of individuals living with diabetes. This allows the definition of vulnerable groups of T2D persons and the establishment of corresponding prevention measures.

Discussion

This study revealed the strong impact of the ongoing war on health of patients living with diabetes, revealing an increased risk of T2D progression. This finding aligns with the previously established fact that armed conflicts cause not only deaths and injuries on the battlefield, but also heavily affect civil population and healthcare at various levels.[10] Stress, basic goods shortage and breakdown of social and health services enhance the risk of onset and progression of various non-communicable diseases (NCDs).[11,12] There is a growing body of evidence illuminating the destructive effect of the war on cardiovascular pathology, stroke incidence, renal failure, cancer and women health.[7,13,14] Previous meta-analysis revealed that armed conflict is associated with an increased coronary heart disease, cerebrovascular events, cancers and endocrine pathology.[15,16] These data are supported by recent observation within Ukraine demonstrating the increased rate of ischemic stroke and the challenges faced by patients on dialysis, and by our study, reflecting the long-term footprint of the war on the civil population health and wellbeing.[14,17]

Moreover, we found a cumulative effect of war-related factor exposure on T2D individuals' health, with a progressive increase in HbA1c levels and an increase in the percentage of patients with poor glycemic control. The significant increase in HbA1c levels was chronologically related to previous massive attacks on energy infrastructure following the electric power crisis. This was wintertime accompanied by the disruption of public access to water, electricity, heat, healthcare, education, and social protection. Many Ukrainians live in damaged homes or buildings that are ill prepared for life-threatening freezing temperatures.[18]

As the war continues, humanitarian needs are multiplying and spreading. Previous studies demonstrated that missile attacks and bombings caused the death of armed staff and civilians but also resulted in the destruction of civil objects and healthcare institutions, heavily affecting the healthcare system and affordability of diagnostic and therapeutic facilities for various patients' needs.[19]

By assessing the most important factors undermining health of people living with diabetes, we identified the set of intrinsic and war-related variables affecting the T2D course. The initial HbA1c level is among the most essential prognostic factors for identifying the group of patients with low HbA1c with initial metabolic disturbances as the most vulnerable to T2D progression.

Military actions and occupation experience, as well as displacement, were the most crucial war-related factors increasing the risk of T2D progression.

Indeed, the war aggravated the level of stress, inducing emotional and consequent hormonal stress reactions to traumatic events.[20] Prolonged exposure to

Variables	Model coefficients, b ± m	Level of significance, p	Odds ratio (95% CI)
Univariate logistic regression analysis			
Gender			
Men	Reference		
Women	0.03 ± 0.13	0.792	0.97 (0.75–1.25)
Age, years	−0.006 ± 0.006	0.306	0.99 (0.98–1.01)
Weight, kg	0.002 ± 0.004	0.319	1.00 (0.99–1.01)
Height, cm	−0.002 ± 0.008	0.789	1.00 (0.98–1.01)
Diabetes duration, years	−0.011 ± 0.009	0.197	0.99 (0.97–1.01)
HbA1c before the war	−0.27 ± 0.04	**<0.001**	**0.76 (0.70–0.83)**
BMI, kg/m^2	0.011 ± 0.011	0.367	1.01 (0.99–1.03)
BMI			
<30	Referent		
≥30	0.04 ± 0.13	0.765	1.04 (0.80–1.35)
Age group			
<45	Referent		
45–60	−0.40 ± 0.28	0.161	0.67 (0.38–1.17)
61–75	−0.36 ± 0.28	0.199	0.70 (0.40–1.21)
>75	−0.30 ± 0.34	0.367	0.74 (0.38–1.43)
Periods (duration of exposure)			
1	Referent		
2	0.96 ± 0.20	**<0.001**	**2.62 (1.76–3.92)**
3	0.66 ± 1.30	0.612	1.93 (0.15–24.6)
4	1.09 ± 0.34	**0.001**	**2.98 (1.53–5.79)**
5	1.19 ± 0.33	**<0.001**	**3.29 (1.73–6.26)**
6	1.20 ± 0.26	**<0.001**	**3.34 (2.02–5.50)**
7	1.26 ± 0.25	**<0.001**	**3.53 (2.17–5.75)**
Experience of military aggression			
No	Referent		
Yes	0.47 ± 0.15	**0.002**	**1.60 (1.20–2.15)**
Experience of occupation			
No	Referent		
<2 weeks	0.30 ± 0.25	0.247	1.34 (0.82–2.21)
2–4 weeks	0.31 ± 0.23	0.191	1.36 (0.86–2.15)
>4 weeks	0.72 ± 0.22	**0.001**	**2.06 (1.34–3.17)**
Forced displacement			
No	Referent		
Displaced in Ukraine	0.37 ± 0.16	**0.018**	**1.44 (1.06–1.96)**
Abroad	0.04 ± 0.47	0.926	1.04 (0.42–2.61)
Displacement duration			
Short-term	Referent		
Long-term	0.30 ± 0.15	**0.041**	**1.36 (1.01–1.82)**
Family separation			
No	Referent		
Yes	0.32 ± 0.27	0.227	1.38 (0.32–2.34)
Relatives affected			
0	Referent		
1	0.33 ± 0.15	**0.031**	**1.39 (1.03–1.87)**
Region of living			
West	Referent		
North	0.41 ± 0.17	**0.020**	**1.50 (1.07–2.11)**
East	0.83 ± 0.22	**<0.001**	**2.29 (1.49–3.52)**
Center	0.14 ± 0.18	0.591	1.15 (0.80–1.65)

(Table 3 continues on next page)

Variables	Model coefficients, b ± m	Level of significance, p	Odds ratio (95% CI)
(Continued from previous page)			
South	0.61 ± 0.33	0.065	1.84 (0.96–3.53)
Glucose control maintenance			
Yes	Referent		
Irregular	0.43 ± 0.16	**0.008**	**1.53 (1.12–2.10)**
No opportunity	0.81 ± 0.21	**<0.001**	**2.25 (1.49–3.40)**
Hypoglycemia			
No	Referent		
Yes	−0.19 ± 0.15	0.209	0.82 (0.61–1.15)
Endocrinologist support			
Yes	Referent		
Yes, online	0.42 ± 0.20	**0.033**	**1.52 (1.03–2.25)**
No	0.66 ± 0.17	**<0.001**	**1.93 (1.38–2.70)**
Diet maintenance			
No	Referent		
Yes	−0.33 ± 0.14	**0.017**	**0.72 (0.55–0.94)**
Phys activity			
No	Referent		
Yes	−0.27 ± 0.14	**0.047**	**0.76 (0.59–0.99)**
Multivariate logistic regression analysis			
Variables	Model coefficient, b ± m	Level of significance, p	Odds ratio (95% CI)
HbA1c before the war	−0.30 ± 0.05	**<0.001**	**0.74 (0.68–0.81)**
Period (duration of the war)			
2	Reference		
3	0.96 ± 0.20	**<0.001**	**2.62 (1.76–3.92)**
4	0.66 ± 1.30	0.612	1.93 (0.15–24.6)
5	1.09 ± 0.34	**0.001**	**2.98 (1.53–5.79)**
6	1.19 ± 0.33	**<0.001**	**3.29 (1.73–6.26)**
7	1.20 ± 0.26	**<0.001**	**3.34 (2.02–5.50)**
8	1.26 ± 0.25	**<0.001**	**3.53 (2.17–5.75)**
Occupation duration			
No	Reference		
<15 days	0.23 ± 0.29	0.434	1.26 (0.71–2.24)
16–30 days	0.12 ± 0.27	0.191	1.13 (0.67–1.90)
>1 month	0.53 ± 0.25	**0.033**	**1.71 (1.04–2.79)**
Glucose control			
Yes	Reference		
Irregular	0.86 ± 0.20	**<0.001**	**2.35 (1.58–3.52)**
No	1.22 ± 0.26	**<0.001**	**3.39 (2.03–5.65)**

The bold indicates significant changes.

Table 3: **Parameters of logistic regression models uncovering different variables impact on T2D progression during the war.**

stressful events or family member loss can also increase the severity of mental disorders and the corresponding alterations in physical health.[21] With respect to the long-term health trajectory of people after their war experience, Wagner J. et al. reported high rates of cardiometabolic pathology, including T2D, among refugees.[22] Moreover, the authors revealed unique risk factors, which included a history of malnutrition, psychiatric disorders, lifestyle changes, social isolation, and a poor profile of the social determinants of health.[22] In contrast to refugees moving abroad, internally displaced persons still have been living within Ukraine after the stress of relocation, underexposure to the war hazards combined with challenges related to new settlements, loss of assets, social and work networks, as well as economic imbalance.[23] Previous studies confirmed that internally displaced persons experience greater rates of illness and death than the baseline in their country.[24–26]

In addition to the direct effects of military aggression, war can affect T2D persons' health indirectly through mental health problems, inducing distress, depression, or posttraumatic stress disorder (PTSD), which are associated with dramatic disturbances in metabolic control. Traumatic events and corresponding memories can trigger PTSD development.[27] Importantly, individuals with comorbid PTSD and T2D had worse outcomes than those with T2D alone did, demonstrating a greater risk of microvascular complications.[28] Moreover, people with PTSD were shown to be at increased risk for developing T2D.[28]

On the other hand, diabetes can in turn exacerbate the development of depression, as the incidence of depression is twice as high in people with diabetes mellitus than in the general population, although during peaceful times, the majority of cases are underdiagnosed.[29] Steel et al. reported that 30% of refugee adults experience PTSD and that more than 30% have depression.[30] Similar data were obtained by other authors during the war in Ukraine.[31] War-related threats drive people to live in "a state of limbo and uncertainty" with extensive concerns about economic issues, living conditions, hygienic and sanitary supplies, access to necessities, the affordability of medications and healthcare professionals, safety and the future,[32] the feeling of loss of social support facilitating anxiety and depression, concerns about safety and the future, and the risk of conflict escalation, including a nuclear threat.[33] Therefore, T2D persons may be prone to developing mental disorders under war circumstances that create a vicious cycle of aggravated T2D and mental health problems. Although we did not address the questions concerning mental health during the survey, these facts and uncovered links between T2D and military action-related experience address the need for additional psychological assessment of all individuals with newly diagnosed T2D during the war.

The war-related conditions and massive displacement also deprive peoples living with diabetes of usual healthcare settings. According to the study, approximately 21.2% of the respondents lost contact with endocrinologists, and 13.7% had only online communication. This was closely related to a lack of or irregular glucose monitoring, diet alterations and reduced access to medications, providing challenges for therapy correction.[34] Indeed, the high levels of psychological distress in people experiencing a war hamper

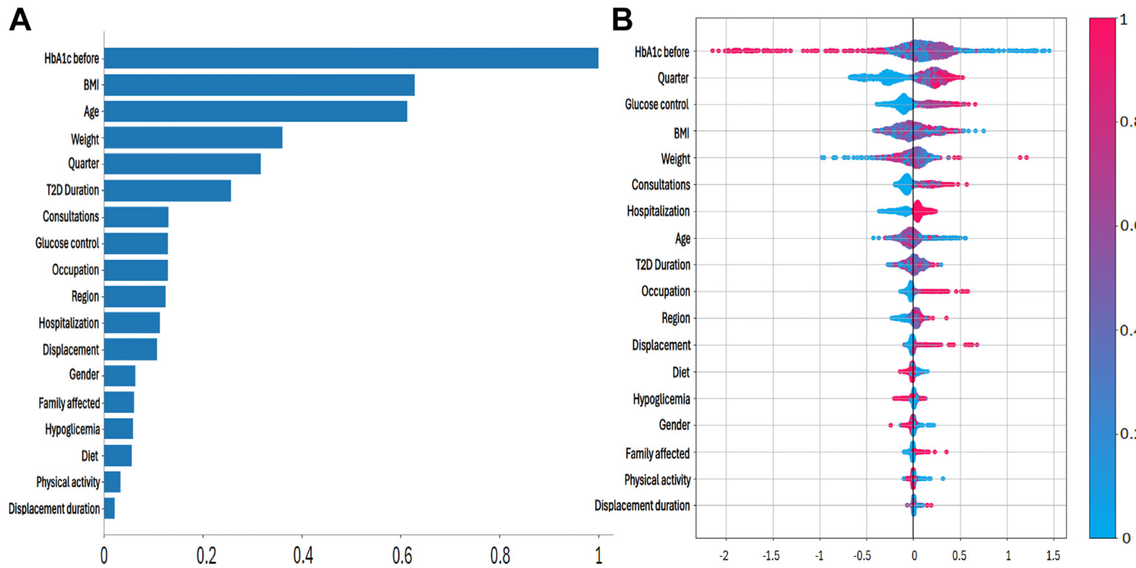

Fig. 3: The list and impact of the most important variables affecting T2D prognosis in the top model. A—The chart shows the set of the top features defining the differences between progressors and patients with stable T2D courses. B—SHAP analysis of the most effective classification model, showing the overall impact of each feature. In addition to highlighting the importance of the features, this analysis also demonstrates the range of their significance. Each row in the figure corresponds to a specific feature, with the x-axis representing the SHAP value. The data points are colored, with red indicating higher values and blue indicating lower values.

lifestyle change efforts, leading to poor diet and physical activity inconsistency.[35] Herein, we showed that a lack of regular glucose monitoring was also a risk factor facilitating T2D progression. Neuman V et al. focused on the care of war refugee children with T1D and highlighted the significance of early and continuous glucose monitoring in HbA1c level control in war refugee children with no relation to their background.[36,37] It was also highlighted that food and pharmaceutical deliveries had been disrupted during the war in Ukraine especially in the occupied territories.[34] This resulted in a scarcity of vital medications and food which is essential for patients with diabetes.

Finally, social determinants of health, defined as any social, economic, or environmental factor that influences a health outcome, are also worth noting in the context of diabetes progression under the war. It was demonstrated that economic circumstances, social isolation, altered social roles, loneliness, discrimination, etc can impact NCDs, including T2D.[38] Our models demonstrated that although the war significantly influences T2D progression, adequate T2D management remains important for maintaining health of individuals living with diabetes. Additional attention should be given to people with milder T2D, as they are most vulnerable to such conditions, with a focus on the affordability of glucose monitoring tools and the regular support of healthcare professionals. Specific attention should be given to vulnerable groups, including internally displaced persons, with respect to Eastern and Northern Ukraine, which are people who experienced military attacks and occupations. A close and mutual link between T2D and mental disorders also dictated the need for additional assessment of patients. Given that the history of PTSD is related to high levels of T2DM among displaced people regardless of comorbid depression, healthcare providers and policymakers need to consider PTSD when assessing and treating T2D among vulnerable migrant populations.[39]

The lessons learned through the experiences of other countries that faced military conflicts and humanitarian catastrophes could include digital tools for supporting patients and the education and empowerment of T2D individuals. These measures were suggested to be effective for coping with mental problems, regular glucose monitoring and promoting rational dietary and lifestyle behavior for mental and physical well-being despite the challenges of the war.[35] In addition, professionals in mental health issues recommend shifting the focus from war to positive events and activities to reduce the burden of war-induced stress.[40] Addressing social determinants of health it seems important to provide multidimensional support assuring financial and non-financial security of displaced people and individuals living in poverty.[41] Moreover, more efforts should be focused on improving diabetes knowledge and self-care skills among primary care patients with type 2 diabetes.[42]

The finding of the study enables to depict the group of patients with the highest risk of diabetes progression after facing war-related threats. These data can navigate in developing policies, practical guidelines and effective action plans for helping peoples living with diabetes during the ongoing war, tailoring their management and preventing disease progression. Prevention of physical and mental health disorders in patients with metabolic disturbances, experiencing war trauma and associated factors, is of the highest demand in Ukraine. There is a need for systematic data collection, evaluation and correction actions for improving diabetes care, especially in vulnerable geographic areas. Extrapolating the data of this study at a global scale is essential for developing robust strategies and clear action plans to support peoples living with diabetes in humanitarian disasters. The global community has been playing an essential role in providing humanitarian aid, financial and intellectual support to Ukraine during the war. International organizations including WHO, UNICEF, IDF, EASD, "Doctors without borders" and many others clearly articulated their position, advocating continuous support of medicines and diagnostic material from manufacturers and volunteers to support Ukraine, Ukrainian physicians and many people living with diabetes. The support of global community, multiple projects and initiatives from professional associations, global organizations and groups defines the resilience of Program of Medical Guarantees released by the National Health Services of Ukraine, helps to restore healthcare facilities, including primary health care centers and adjust them to the threats of war, and provides essential medications and tools for individuals with diabetes. Many actions are focused on supporting resilience, preparedness, and recovery of the affected by war health system, improving mental health, supporting safe and proper access to quality health care services for ensuring continuity of care. Although the common efforts on recovering and strengthening of diabetic care in Ukraine are tremendous there are still unmet needs of people with diabetes. Ukrainian healthcare system faces the shortage of qualified personnel and resources that fosters implementation of digital tools and patient empowerment.

In summary, the dramatic effects of the war on health of persons living with diabetes and uncovered risk factors, together with the lessons learned from other populations' experiences, are essential for providing better T2D persons support, preventing diabetes complications and developing efficient medical care in the future.

The data of the study were collected by the survey, at a single time point with retrospective data collection. The data were collected by convenience sampling which defines a possible bias of the data obtained. The findings of this cross-sectional reflect the associations rather than the causative effect of war-related factors on health outcomes of people with T2D. Further large-scale studies and follow-up with precise clinical, laboratory and health history data are needed. Besides, this study addressed only the relation between war-related factors and the health of persons with T2D, but not type 1 diabetes. Future research assessing both the physical and mental health of individuals living with type 1 and type 2 diabetes during the war and their outcomes is needed. This study also did not include the issues related to hyperglycemic crises (such as diabetic ketoacidosis and hyperosmolar hyperglycemic state). Another important limitation that access to and availability of medicines was not taken into account in this study.

Contributors

OS and NK conceived the study, developed the protocol, led the data approvals, and wrote the first draft of the manuscript. VG, DK and OG performed the statistical analysis. VY, SZ, IK, TO, VY, TY, TA, VP, ZS, TF, NS, TR, TK, NP, SD, and AK provided critical feedback throughout the project to shape the analysis and the manuscript. OS and NK provided study leadership. OS, NK and VG accessed and verified data. All authors were permitted full access to the study data, approved the final submission, and accepted responsibility for the decision to submit for publication.

Data sharing statement

Deidentified individual participant data that support the findings of this study are available upon request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Declaration of interests

All authors declare no competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.eclinm.2024.103008.

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