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PROGNOSTIC ASSESSMENT OF RISK FACTORS FOR TYPE 2 DIABETES MELLITUS IN YOUNG MILITARY PERSONNEL

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ABSTRACT: Risk factors for the development of type 2 diabetes mellitus were assessed in 212 military personnel aged 20–45 years serving under a contract, of which 95 people (an experienced group with risk factors) and 117 people without risk factors (an experienced group), as well as 60 practically healthy males who are not military personnel Ministry of Defense of the Russian Federation aged between 18 and 45 years (control group). It was revealed that the indicators with the greatest influence on the development of type 2 diabetes include older age, body mass index, waist circumference, insulin resistance index, and the results of the psychological questionnaire "Tendency to deviant behavior" on the scale of "Aggressiveness" as well as the questionnaire "Strong-willed self-control." It was found, on 3-year follow-up, that prediabetes developed in 8 (8.4%) patients of the experimental group with risk factors for type 2 diabetes mellitus who did not have carbohydrate metabolism disorders, and in 8 (6.8%) patients of the experimental group. At the same time, type 2 diabetes mellitus occurred in 2 (2.5%) patients of the experimental group and in 2 (1.7%) military personnel of the experimental group with risk factors for type 2 diabetes but initially normal glycemic indices, as well as in 8 (8.4%) patients of the same group who had prediabetes at the beginning of the study. In addition, prediabetes was detected in 2 people of the control group after 3 years and type 2 diabetes mellitus in 1 person. According to the results of the study, a mathematical model is proposed to assess the likelihood of developing type 2 diabetes in military personnel with a waist circumference ≥94 cm. The proposed model has a sensitivity of 95% and a specificity of 91%. The prognostic value of a negative result is 89.2%, and that of a positive result is 87%. Thus, military personnel with a waist circumference of ≥94 cm are characterized by a more frequent development of new cases of prediabetes and type 2 diabetes mellitus than civilians, which is due to the stressful nature of military service. The use of the proposed mathematical model will make it possible to predict the development of carbohydrate metabolism disorders in military personnel with a waist circumference of ≥94 cm over a 3-year period with the identification of a risk group requiring the use of a set of preventive measures aimed at reducing body weight.

Keywords: diabetes mellitus; body mass index; mathematical model; insulin; carbohydrate metabolism disorder; prediabetes; psycho-emotional stress.

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ПРОГНОСТИЧЕСКАЯ ОЦЕНКА ФАКТОРОВ РИСКА САХАРНОГО ДИАБЕТА 2-го ТИПА У ВОЕННОСЛУЖАЩИХ МОЛОДОГО ВОЗРАСТА

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Резюме. Оцениваются факторы риска развития сахарного диабета 2-го типа у 212 военнослужащих в возрасте от 20 до 45 лет, проходящих службу по контракту, из них 95 человек (опытная группа с факторами риска) и 117 человек без факторов риска (опытная группа), а также 60 практически здоровых лиц мужского пола, не являющихся военнослужащими Министерства обороны Российской Федерации в возрасте от 18 до 45 лет (контрольная группа). Выявлено, что к показателям, обладающим наибольшим влиянием на развитие сахарного диабета 2-го типа, относятся более старший возраст, индекс массы тела, окружность талии, индекс инсулинорезистентности и результаты психологического опросника «Склонность к отклоняющемуся поведению» по шкале «Агрессивность» и опросника «Волевой самоконтроль». Установлено, что через 3 года наблюдения предиабет развился у 8 (8,4%) пациентов опытной группы с факторами риска развития сахарного диабета 2-го типа, но не имевших нарушений углеводного обмена, и у 8 (6,8%) пациентов опытной группы. При этом сахарный диабет 2-го типа дебютировал у 2 (2,5%) пациентов опытной группы и у 2 (1,7%) военнослужащих опытной группы с факторами риска развития сахарного диабета 2-го типа, но с исходно нормальными показателями гликемии, а также у 8 (8,4%) пациентов этой же группы, имевших в начале исследования предиабет. Кроме того, у 2 человек контрольной группы через 3 года был выявлен предиабет и у 1 человека, сахарный диабет 2-го типа. По результатам исследования предложена математическая модель для оценки вероятности развития сахарного диабета 2-го типа у военнослужащих, имеющих окружность талии ≥ 94 см. Предлагаемая модель имеет чувствительность 95%, специфичность 91%, прогностическую ценность отрицательного результата 89,2%, прогностическую ценность положительного результата 87%. Таким образом, военнослужащие, имеющие окружность талии ≥ 94 см характеризуются более частым, чем у гражданских лиц, развитием новых случаев предиабета и сахарного диабета 2-го типа, что обусловлено стрессогенными особенностями военной службы. Использование предлагаемой математической модели позволит прогнозировать развитие нарушений углеводного обмена у военнослужащих, имеющих окружность талии ≥ 94 см в течение трехлетнего периода с выявлением группы риска, требующей применения комплекса профилактических мер, нацеленных на снижение массы тела.

Ключевые слова: сахарный диабет; индекс массы тела; математическая модель; инсулин; нарушение углеводного обмена; предиабет; психоэмоциональный стресс.

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BACKGROUND

Type 2 diabetes mellitus (T2DM) is a serious chronic disease and a significant public health problem because of its considerable effect on health due to the high risk of occurrence and development of severe complications, which affect directly the socio-economic well-being of the population. Since 2000, the number of patients with DM in the Russian Federation (RF) has grown 2.2 times, i.e., from 2.043 million to 4.58 million [1]. Obviously, these figures do not reflect the true scale of the non-infectious "epidemic" because only identified DM cases are registered. According to the NATION national epidemiological study, which included more than 26 thousand people in 63 constituent entities of the RF, the proportion of undiagnosed T2DM in Russia averages 54% [2]. Every second (50.1%) patient with T2DM does not know about it. Moreover, statistics indicate a higher incidence of metabolic syndrome components in those who are professionally associated with a high psychoemotional load. This is important for people serving in security, defense, and law-enforcement agencies because their work is associated with a high risk of psychoemotional and physical stress, and the state of health of military personnel affects directly the combat capability of the army and security of the state [3, 4]. Currently, there is a trend toward an increase in the incidence of DM among military personnel and pensioners of the Ministry of Defense (MD) of the RF [4]. In recent years, owing to the increase in the limit of military service, the number of persons undergoing enlistment by contract, with an average age of 35–40 years, has increased, which may lead to an increased risk of T2DM. In turn, existing methods for assessing T2DM risk do not reflect the contribution of psychoemotional stress to disease development. In modern literature, there is not enough information on quantifying these factors in relation to the risk of prediabetes and T2DM in people who are professionally associated with a high psychoemotional load. In this regard, the prediction and early detection of prediabetes and T2DM in this cohort with carbohydrate metabolism disorders are relevant.

The study aimed to identify risk factors for T2DM development and evaluate their prognostic significance in young military personnel.

MATERIALS AND METHODS

This prospective cohort study was conducted among military personnel of the RF MD. The study group included participants from among the military personnel who were enlisted by contract. Mandatory criteria for inclusion in the experimental group (EG) without risk factors for T2DM were military service enlistment in RF MD by contract during the study period, male sex, and waist circumference (WC) of ≥ 94 cm. Additional inclusion criteria for the EG with risk factors (EGRF) (any or combination thereof) were prediabetes (impaired fasting glycemia or impaired glucose tolerance) on capillary blood tests [fasting glycemia ≥ 5.6 and < 6.1 mmol/L; glycemia 2 h after oral glucose tolerance test (OGTT) ≥ 7.8 and < 11.1 mmol/L], previously confirmed cholesterol level of ≥6 mmol/L or low-density lipoprotein (LDL) of ≥ 3 mmol/L, and blood pressure of ≥ 140/90 mm Hg. The exclusion criteria were age > 45 years, confirmed diagnosis of T1DM or T2DM based on OGTT results, and non-compliance with the inclusion criteria. The control group (CG) consisted of 60 apparently healthy men who were not military personnel of the RF MD, aged 18–45 years, and had WC of ≥ 94 cm. The age range of participants is presented in Table 1.

In stage 1 of the study, the diagnostic algorithm included an assessment of anthropometric data [height, body weight, body mass index (BMI), and WC], and biochemical blood test, including venous plasma glucose, total cholesterol (TC), LDL, total bilirubin, and urea, was performed on an Architect plusC4000 Biochemical Analyzer using the manufacturer's reagents. OGTT was performed by analyzing capillary blood using an Accu-Chek Active glucometer with standardized test strips. Hormonal blood tests including the determination of immunoreactive insulin and C-peptide levels were performed by enhanced chemiluminescence on a COBAS 6000 analyzer (Roche Diagnostics, IN, USA). Based on the data obtained, the Homeostatic Model Assessment of Insulin Resistance

Table 1. Age range of patients in the examined groups, *n* (%)
Таблица 1. Возрастной диапазон пациентов обследованных групп, абс. (%)

Indicator	EGRF and EG	CG
Total patients examined	212	60
20–25 years	58 (27.5)	2 (3.33)
26–35 years	80 (37.5)	35 (58.33)
36–45 years	74 (35)	22 (36.67)

(HOMA-IR) index (homeostasis model assessment) was calculated using the following equation:

$$\text{HOMA-IR}=\frac{\text{IRI} \cdot \text{Gl}}{22.5} \quad [5],$$

where IRI is the immunoreactive insulin (mcU/m) and Gl is glucose (mmol/L).

Insulin resistance was diagnosed when the HOMA-IR index was > 2.77 [6].

To assess the possible effect of the psychological characteristics of an individual on T2DM development, we used data from questionnaires used in the annual examination of military personnel, including an individual typological questionnaire + / −1 developed by Sobchik, consisting of 91 questions, with the completion time of 30 min. In the assessment of the military personnel, three parameters were identified and evaluated separately, namely, "disadaptation," "aggression", and "depression" [7]. The questionnaire developed by Oryol enables determining the propensity for positive deviant behavior (PDB). It represents a set of specialized psychodiagnostic scales aimed at determining the readiness (inclination) to implement certain forms of deviant behavior. The questionnaire scales are divided into informative and service. In the assessment of military personnel, "nonconformism", "aggressiveness", and "desirability" scales were used [8]. The "volitional self-control" questionnaire developed by Zverkov and Eidman aimed at self-evaluation of the development of volitional regulation, which is understood (in the most general form) as a measure of controlling one's behavior in various situations, i.e., the ability to control consciously one's actions, states, and impulses. The "volitional self-control" questionnaire contains 30 items, including 24 working items and 6 camouflage items. Subscale 1 characterizes the available conscious mobilization energy potential for completing an action, and subscale 2 indicates the level of voluntary control of emotional reactions and states. In terms of traditional volitional personality traits, subscale 1 was named "perseverance," and subscale 2 was named "self-control" [9].

To assess physical activity, a motor activity questionnaire (ODA23+) was used, which revealed that all participants had moderate physical activity, without a statistically significant difference between them. Then, carbohydrate metabolism was assessed after 3 years. The study design is presented in Figure 1.

Data were statistically analyzed using Statistica 10.0 and SPSS Statistics 17.0. Summary spreadsheets were formed based on formalized survey maps in Microsoft Excel. To examine the correlations between indicators, the Spearman rank test was used; the correlation coefficients (ρ) and significance level (*p*) were calculated. Differences between

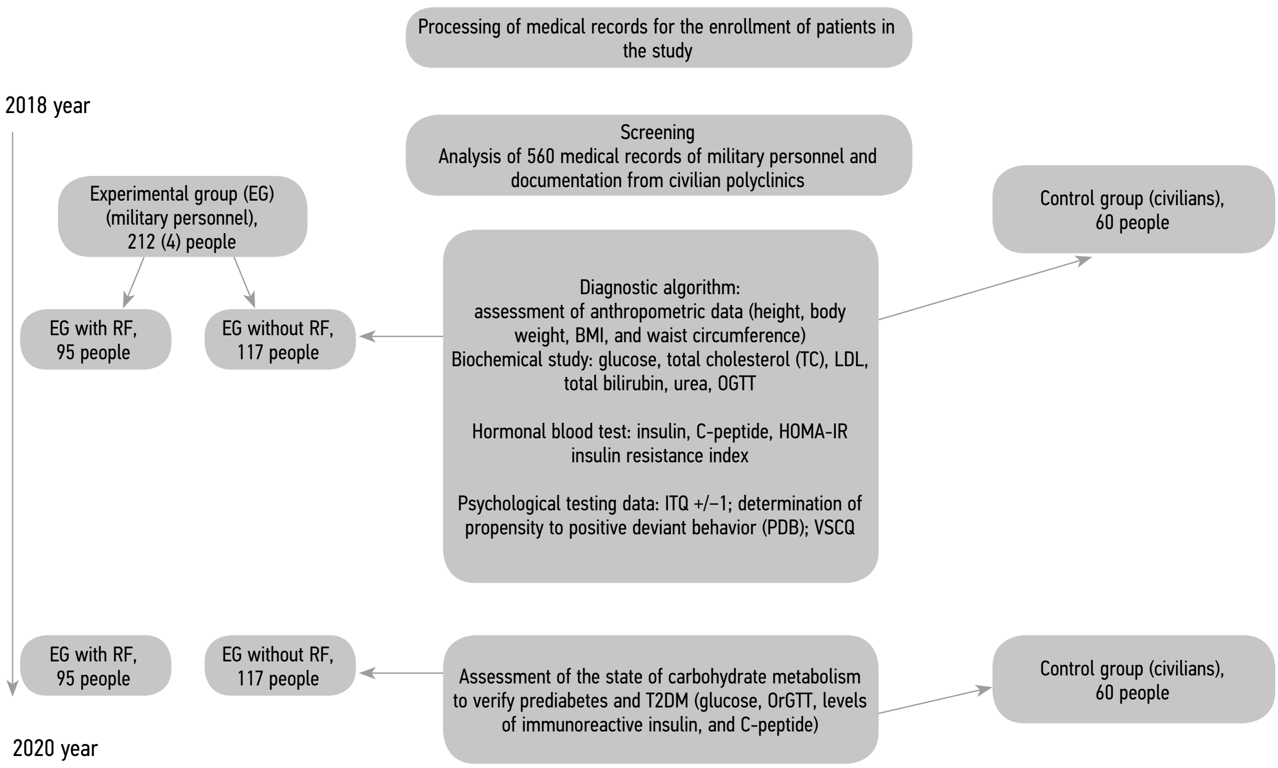

Figure. Study design. FR — risk factors; LDL — low-density lipoproteins; PGTT — oral glucose tolerance test; VSK — questionnaire "Volitional self-control"; OGTT — oral glucose tolerance test

Рисунок. Дизайн исследования. ФР — факторы риска; ЛПНП — липопротеины низкой плотности; ПГТТ — пероральный глюкозотолерантный тест; ВСК — опросник "Волевой самоконтроль"; ОГТТ — оральный глюкозотолерантный тест

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groups were examined using the Mann–Whitney *U*-test. A significance level of $p = 0.05$ was adopted. Prognostic assessment of indicators was performed using receiver operating characteristic (ROC) analysis, and their sensitivity and specificity were calculated. To obtain a mathematical model for calculating the T2DM risk, binary logistic regression was used. The results obtained are presented as *Me* [X_{min}; X_{max}], where *Me* is the median of parameter analyzed, and [X_{min}; X_{max}] is the sample range.

RESULTS AND DISCUSSION

Normal glucose levels were registered in 168 patients, and borderline glucose levels (5.5–6.1 mmol/L) were noted in 46 participants who required OGTT [10]. Two participants had T2DM; therefore, they were withdrawn from the study. In the OGTT, 44 patients had impaired fasting glycemia.

Overweight was detected in 52 patients in the EG and 46 in the EGRF. In addition, 27 patients in the EG and 46 in the EGRF were diagnosed with grade I obesity. In the rest ($n = 41$) of the participants, body weight and BMI were within the reference values. The average WC index values were 100.5 and 99.2 cm and the median values were 99 and 98 cm in the EGRF and EG, respectively. In the EG, the median cholesterol level was 4.8 mmol/L, with minimum and maximum values of 2.3 and 6 mmol/L, respectively. In the EGRF, the median cholesterol level was 5 mmol/L, with minimum and maximum values of 2.3 and 8.1 mmol/L, respectively. In the EG, the median LDL value was 2.44 mmol/L, with minimum and maximum values of 1.64 and 2.98 mmol/l, respectively. In the EGRF, the median LDL level was 2.98 mmol/L, and the minimum and maximum values were 1.64 and 4.5 mmol/L, respectively. In the EG, the median urea level was 6.1 mmol/L, which ranged from 3.4 to 8.7 mmol/L. In the EGRF, the median urea level was 6.2 mmol/L, and the minimum and maximum values were 3.4 and 8.7 mmol/L, respectively.

The insulin level in the EGRF exceeded those in the EG and CG (median 12.20 vs 8.35 vs 5.15 μU/mL, respectively, $p < 0.0001$). The HOMA-IR index also differed statistically significantly in the EGRF and exceeded those in the EG and CG (median 2.77 vs 1.94 vs 1.12, respectively, $p < 0.0001$). The glucose level in the EGRF exceeded those in the EG and CG (median 5.5 vs 5.2 vs 4.6 μU/mL, respectively, $p < 0.0001$).

Moreover, participants with obvious disorders of carbohydrate metabolism, that is, with a fasting blood glucose level >6.1 mmol/l, were not included in the study.

Based on the above data and the increased fasting blood serum level of insulin, i.e., higher insulin resistance indices in military personnel than in CG, military labor factors were found to influence significantly the development of insulin resistance and the determination of carbohydrate metabolism disorders.

The outcomes of participants with prediabetes and T2DM after 3 years are presented in Table 2. Moreover, in the CG, prediabetes was detected in two patients, and T2DM was found in one patient, which was slightly lower than that in EG and EGRF.

The results of a psychological examination according to the PDB questionnaire (“aggressiveness” scale) and the “volitional self-control” questionnaire are presented in Table 3.

Table 2. Outcome of subjects with prediabetes and DM2, people
Таблица 2. Исход участников эксперимента в предиабет и СД2, чел.

Examination	EG		EGRF				CG	
Initial	Euglycemia 117		Prediabetes 44		Euglycemia 51		Euglycemia 60	
After 3 years	Prediabetes 8	T2DM 2	Prediabetes 36	T2DM 8	Prediabetes 8	T2DM 2	Prediabetes 2	T2DM 1

Table 3. Psychological examination data in all groups, points (*Me* [X_{min}; X_{max}])
Таблица 3. Данные психологического обследования во всех группах, балл (*Me* [X_{min}; X_{max}])

Indicator	EG	EGRF	CG
Scale “A”: aggressiveness	4 [2; 7]*	5 [1; 9]*#	3 [2; 3]
Questionnaire “B”: volitional self-contro	4 [2; 6]*	4 [1; 7]*#	8 [6; 9]

* — difference between EG, EGRF, and CG; # — difference between EG and EGRF, $p < 0.0001$.

In stage 2, in the EG and EGRF, a possible correlation between the obtained indicators at the initial stage and T2DM detection after 3 years of follow-up was investigated. In this case, only statistically significant correlations were considered. A statistically significant negative correlation of moderate strength in the examined groups was registered between the level of fasting blood glucose and parameters of volitional self-control questionnaire (ρ = –0.601; p = 0.0003). The same but positive relationship was noted between body weight (including BMI) and the “aggressiveness” scale of the PDB questionnaire (ρ = 0.603; p < 0.05). Moreover, a positive correlation of average strength was found between BMI and “working capacity” (ρ = 0.490; p < 0.05). A high “depression” score was statistically significantly (p < 0.05) associated (ρ > 0.5) with elevated cholesterol levels. In addition, the relationship between age, BMI, insulin, HOMA-IR index, and psychological examination indicators and the emergence of carbohydrate metabolism disorders was assessed (Table 4).

In addition, a statistically significant positive correlation of moderate strength was found between older (aged 36–45 years) servicemen and occurrence of pathology in 3 years (ρ = 0.470; p < 0.05) and between anthropometric data, insulin resistance indicators, and psychological state of the servicemen. The older the age, the higher the BMI, WC, and insulin resistance index and the higher the PDB score on the aggressiveness scale; however, the lower the level on the volitional self-control questionnaire, the higher the probability of T2DM development in the next 3 years.

Positive statistically significant correlations of moderate strength were noted between BMI and diabetes onset (ρ = 0.540; p < 0.05). WC also correlated positively with the occurrence of carbohydrate metabolism disorders (ρ = 0.611; p < 0.05). The insulin level and HOMA-IR index positively, statistically, and significantly correlated with T2DM development in the EGs (ρ = 0.606 and ρ = 0.589, respectively, p < 0.05). Psychological examination according to the PDB questionnaire (aggressiveness scale) showed a positive correlation of moderate strength (ρ = 0.627; p < 0.05). In addition, the volitional self-control questionnaire score revealed a negative correlation of moderate strength (ρ = –0.601; p < 0.05) with T2DM development in 3 years of follow-up. When examining the relationship between fasting blood glucose levels and diabetes onset, only a weak correlation was detected, with a coefficient of 0.213 (p > 0.05). Correlations were also tested with other indicators.

To study the predictive value of the above indicators that contribute to T2DM development in military personnel, an ROC analysis was performed. The analysis included only age, BMI, WC, insulin resistance index, and psychological examination indicators according to the volitional self-control questionnaire and PDB questionnaire (aggressiveness scale) because the correlation coefficients between them and T2DM development were the highest (Table 5).

Table 4. Statistically significant (p < 0.05) correlation coefficients between the indicators of stage 1 and the occurrence of DM2 in military personnel after 3 years
Таблица 4. Статистически значимые (p < 0,05) коэффициенты корреляций между показателями первого этапа и возникновением сахарного диабета 2-го типа (СД2) у военнослужащих через 3 года

Indicator	Age	BMI	WC	Insulin	HOMA-IR index	Aggressiveness	Volitional self-control
Development of T2DM after 3 years	0.470	0.540	0.611	0.606	0.589	0.627	–0.601

Table 5. ROC analysis of the summarized data
Таблица 5. Итоговые данные ROC-анализа

Indicator	Sensitivity, %	Specificity, %	Area under the curve, c.u.	Cutoff point
Age	75	79.4	0.879	37.5
BMI	91.2	33.8	0.938	30.5
Waist circumference	83.3	98.5	0.993	104.0
HOMA-IR index	91.7	94.1	0.976	5.46
PDB “Aggressiveness” scale	90.3	32.1	0.812	2.5
“Volitional self-control” questionnaire	83.3	20.6	0.963	2.5

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The quality of the mathematical model for assessing T2DM risk was determined by the area under the characteristic curve, and the model quality was considered “very good” with values ranging from 0.8 to 0.9 [11]. For all indicators that demonstrated medium and moderate correlations with T2DM development, the area under the characteristic curve was > 0.8, which indicates the high quality of the proposed mathematical model.

In relation to T2DM development in 3 years, the age of military personnel at a cutoff point of 37.5 years had sensitivity and specificity of 75% and 79.4%, respectively. For BMI in the study group, the cutoff point was 30.5 kg/m^2 with sensitivity and specificity of 91.2% and 33.8%, respectively. The highest sensitivity and specificity were demonstrated by indicators such as WC and HOMA-IR index. For WC, the cutoff point was 104 cm, with sensitivity and specificity of 83.3% and 98.5%, respectively. As a prognostic criterion for T2DM development in military personnel, the cutoff HOMA-IR index was 5.46, with sensitivity and specificity of 91.7% and 94.1%, respectively (Table 5).

The scores on the aggressiveness scale of the PDB psychological questionnaire and volitional self-control questionnaire showed a high sensitivity of 90.3% and 83.3%, respectively, but relatively low specificity of 32.1% and 20.6%. The cutoff point was the same for both indicators, which was 2.5 points.

Based on the ROC analysis results, indicators such as older age (aged 36–45 years), BMI, WC, HOMA-IR index, and psychological examination results using the volitional self-control questionnaire and aggressiveness scale of the PDB questionnaire can be used to predict with high accuracy T2DM development in contract military personnel.

Binary logistic regression was used to predict T2DM development in 3 years for each serviceman based on age, BMI, WC, HOMA-IR index, volitional self-control psychological questionnaire, and aggressiveness scale of the PDB questionnaire. Thus, a stepwise regression analysis was performed with the forced inclusion of these indicators of T2DM development. The model with the highest sensitivity, specificity, and negative and positive predictive value of psychological examination result was chosen. After the analysis, a regression equation was obtained, which included all of the above indicators.

Thus, the following equation was obtained to calculate T2DM development in 3 years in military personnel with a WC of ≥94 cm:

$$DP = 1/(1+2.72^{-(0.102 \cdot Age + 0.025 \cdot BMI + 0.493 \cdot WC + 3.475 \cdot HOMA + 8.896 \cdot A - 2.5 \cdot VSC - 114.88)}),$$

where DP is the probability of T2DM development in 3 years; age for a particular serviceman, years; BMI, kg/m^2; WC, cm; HOMA, HOMA-IR index; A, aggressiveness scale score in the PDB psychological questionnaire of 1–10 points; VSC, volitional self-control psychological questionnaire score of 1–10 points.

After entering the data of a specific serviceman and solving the equation, the probability of T2DM development in 3 years can be determined. Thus, using the binary logistic regression method, a mathematical model was obtained to assess the probability of T2DM development in military personnel with WC of ≥94 cm, which included indicators obtained during their annual in-depth medical examination. This model had sensitivity, specificity, negative predictive value, and positive predictive value of 95%, 91%, 89.2%, and 87%, respectively. These data indicated that the mathematical model is sufficiently accurate.

In general, a mathematical model for the probability of T2DM development in young military personnel with WC of ≥94 cm was developed and proposed. In stage 1, according to the results presented in Table 3, the levels of immunoreactive insulin and HOMA-IR index showed statistically significant differences in the groups of military personnel and persons of common professions. According to the psychological examination, the military personnel were characterized by more pronounced emotional tension than the CG because of the peculiarities of military labor, which are associated with intense long-term psychological stress, high cost of error and decision-making, and adverse environmental factors.

Stage 2 included a search for possible correlations between the results obtained in stage 1 and the detection of T2DM after 3 years. A statistically significant positive correlation of moderate strength was detected between older (age 36–45 years) military personnel and T2DM occurrence in 3 years. Positive statistically significant correlations of moderate strength were found between the BMI of military personnel and T2DM occurrence (ρ = 0.545; $p < 0.05$). The WC in the study group correlated positively with the occurrence of carbohydrate metabolism disorders (T2DM) during 3 years of follow-up (ρ = 0.606; $p < 0.05$). This anthropometric parameter enables us to characterize the severity of visceral obesity, which, according to the results of numerous studies, is one of the most important criteria for a metabolically unhealthy phenotype [12, 13]. Insulin levels and HOMA-IR index were statistically, significantly, and positively correlated with T2DM development in servicemen (ρ = 0.606 and ρ = 0.589, respectively; $p < 0.05$). The significance of the HOMA-IR index as a marker of insulin resistance and a risk factor of T2DM was confirmed by Tang et al. [14]. The results of the aggressiveness scale of the PDB psychological questionnaire and volitional self-control questionnaire showed a high sensitivity (90.3% and 83.3%, respectively), but relatively low specificity (32.1% and 20.6% respectively).

In accordance with modern concepts, pronounced anxiety, stress, and lability of the nervous system are significant factors in the development of carbohydrate metabolism disorders. Pathophysiological disorders that occur during stress can be characterized as a series of neuroendocrine changes in the hypothalamus–pituitary zone, leading to changes in the reticular–limbic system and the cerebral cortex. Stress and excessive nervous reactivity are characterized by neurohypophysis and autonomic nervous system disorders with a predominance of sympathetic influences [15]. Further, the adenohypophysis is activated, stimulating the synthesis of glucocorticoids (cortisol) and somatostatin and reducing the generation of opioids (serotonin) and gonadotropic hormones (prolactin, testosterone, etc.). This causes an imbalance of regulators of intracellular processes (cyclic adenosine monophosphate and cyclic guanosine monophosphate) and arachidonic acid metabolites. Cortisol is the main glucocorticoid hormone, and its activity increases sharply during stress [16, 17]. The significance of this factor is indirectly proved by the higher frequency of detection of metabolic syndrome components and insulin resistance in individuals exposed to pronounced psychoemotional influences. Thus, in a study published in *BioMed Central*, which enrolled participants of the operation Desert Storm (n = 253 veterans) who suffered from post-traumatic stress disorder, the incidence of the detected metabolic syndrome was two times higher than the average values of the corresponding age group [18]. Similar data were provided by the US National Institute for Occupational Safety and Health. The incidence of metabolic syndrome in a group of 115 police officers with established post-traumatic stress disorder was three times higher than the average values in the corresponding age groups [19]. According to Russian studies, compared with people of ordinary professions comparable in age, military personnel, as representatives of a hazardous occupation, had a significantly higher incidence of metabolic syndrome because of excessive exposure to psychoemotional stress [4].

Currently, many scales are used to assess T2DM risk. Our study, in general, is a continuation of the largest Russian study DIARISK that focused on the development of the first Russian risk calculator for prediabetes and T2DM, according to which the most significant factors were age ≥ 52 years for women and age ≥ 59 years for men; BMI ≥ 31; WC ≥ 100 cm in women and WC ≥ 112 cm in men; for T2DM, age ≥ 52 years in women and age ≥ 59 years in men, BMI ≥ 31 kg/m^2; elevated fasting blood glucose levels; WC/hip circumference ratio ≥ 0.85 in women and ≥ 0.92 in men; and arterial hypertension. The sensitivity and specificity of the constructed logistic regression model for T2DM are high, with 83.9% and 76.8%, respectively, which is lower than these indicators for our model. A significant difference in our study was the selection of only those individuals who had WC ≥ 94 cm, which predetermined a higher frequency of carbohydrate metabolism disorders and a younger age of military personnel in whom they were detected after 3 years. This confirms the high predictive value of WC ≥ 94 cm as a predictor of metabolic and cardiovascular diseases. In addition, the lower sensitivity and specificity of conventional prognostic models were probably associated with the use of biochemical parameters in our equation (insulin level and HOMA-IR index), which reflect very accurately the level of insulin resistance and are independently significant predictors of T2DM [20]. Moreover, the most important result of the study should be the contribution of psychoemotional stress and neuropsychological characteristics to the development of carbohydrate metabolism disorders in military personnel, which must be taken into account when creating predictive models for this cohort [21]. The mathematical model obtained can contribute to the prevention and early detection of T2DM in personnel with hazardous employment.

CONCLUSIONS

1. The indicators with the greatest influence on T2DM development include older age (36–45 years), BMI, WC, HOMA-IR index, and psychological examination indicators (PDB aggressiveness scale and volitional self-control questionnaire).

2. A mathematical model has been developed for assessing the probability of T2DM development using the binary logistic regression method. The use of the proposed model will enable prediction of T2DM development in military personnel with WC of ≥ 94 cm in 3 years, which will allow identifying a risk group among them that require a set of preventive measures (diet, work and rest regimen, additional physical exercises, weight loss) and additional control by the medical service of the military unit (hospitalization for more in-depth diagnostics). These measures were assumed to prevent T2DM development in this cohort of military personnel.

3. The mathematical model developed has sensitivity, specificity, negative predictive value, and positive predictive value of 95%, 91%, 89.2%, and 87%, respectively.

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