Identifying Risk Factors for Suicide Attempts in Adolescents and Building a Model Using Neural Networks for Predicting Teens at Risk: A Retrospective Epidemiological Study

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ABSTRACT **Background:** Adolescent suicide attempts have well-established risk factors. The increased number of cases at Laniado Hospital's pediatric department over the past decade prompted our evaluation of the relative importance of these factors.

Objectives: To characterize adolescents presenting after suicide attempts and to use these features to develop a neural network for early identification of at-risk youth.

Methods: We conducted a retrospective study of suicide attempts among adolescents (11–18 years) admitted to Laniado Hospital's pediatric department (2015–2021). The study included 82 patients with a matched control group (n=82). We analyzed epidemiological, medical, and psychosocial characteristics, identifying statistically significant factors associated with suicide attempts. We then built a predictive model using neural networks.

Results: Significant risk factors for suicide attempts included living outside original home (odds ratio [OR] 6.71, $P = 0.0002$), female gender (OR 12.67, $P = 0.0502$), unmarried parents (OR=98.51, $P < 0.0001$), advanced age (95% confidence interval [95%CI] 0.477–1.583, $P = 0.0001$), higher hemoglobin (95%CI 0.689–1.81, $P = 6.30 \times 10^{-6}$), higher mean corpuscular volume (MCV) (95%CI 3.61–8.07, $P = 0.014$), and prior psychiatric diagnosis (OR 71.82, $P < 0.0001$). Non-Ashkenazi background was more common but not significant ($P = 0.074$). Our neural network model achieved 99.85% predictive accuracy.

Conclusions: Psychiatric history, unmarried parents, female gender, and living outside the home were the strongest risk factors for adolescent suicide attempts. We observed higher hemoglobin levels and MCV among affected individuals. Our neural network showed high accuracy (99.85%) in distinguishing between adolescents with suicide attempts from matched controls.

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KEY WORDS: adolescents, deep learning, machine learning, neural networks, suicide attempt

Adolescence is considered a critical developmental period, characterized by emotional and social conflicts, tension, and difficulties at school and in the broader environment [1]. To cope with the difficulties they face, adolescents may use different strategies including aggression, rebellion, psychosomatic symptoms, and in extreme cases attempting suicide [1].

Suicide attempts continue to be a significant global health concern affecting teenagers. Adolescents aged 15–19 years have the highest prevalence of self-harming behavior and suicide attempts [2]. Suicide attempts are usually more common in girls than in boys [3]. Poisoning, suffocation, and weapons are the most common causes of suicide, while drug ingestion is the most common method of suicide attempts [3].

There are various known risk factors for suicidal thoughts, suicide attempts, and suicide itself. These factors span across different realms including social, cultural, and environmental influences as well as underlying psychiatric background [4].

For example, teens who exhibit higher levels of agitation and depressive symptoms are at a greater risk for suicide compared to those with lower levels of those symptoms [5].

In addition, teens with attention and concertation disorders also exhibit increased risk for suicide, and treating those conditions stabilizes and lowers the incidence of suicide attempts [6]. Another important risk factor is exposure to negative experiences during childhood. These experiences can increase the risk of suicide attempts by up to five times compared to children who have not faced such challenges (such as exposure to excessive alcohol drinking, consumption of unnecessary and illegal drugs, and other forms of trauma or neglect) [7]. Therefore, identifying and providing appropriate support and treat-

ment to adolescents affected by adverse childhood experiences is crucial in efforts to prevent suicide [8].

At Sanz Medical Center–Laniado Hospital the incidence of admissions to the pediatric department due to suicidal attempts has been rising during the past decade. In response, we initiated a project to collect epidemiological data on all patient admissions due to suicide attempts. Our goals included identifying risk factors among adolescents and characterizing the at-risk population. Furthermore, using this information and neural network models, we attempted to create a predictive tool to help identify adolescents at risk of future suicide attempts.

PATIENTS AND METHODS

Our study is a retrospective cohort study of a group of adolescent patients who attempted suicide. We then compared their characteristics to a control group of adolescents who came to our department because of other etiologies. Furthermore, we created a neural network model to predict which adolescents are at risk of future suicide attempts based on the characteristics we collected.

We analyzed 82 cases of adolescents (ages 11–18) who presented to the pediatric department at our hospital, following suicide attempts between 1 January 2015, and 31 December 2021. We then collected different characteristics of those patients including demographics (e.g., age, gender, ethnicity), clinical background (i.e., medical history, treatments), psychiatric diagnoses (e.g., agitation, eating disorders, attention-deficit/hyperactivity disorder, previous suicidal attempts, alcoholism, drug use, sexual abuse, depression, personality disorder, borderline personality, anxiety disorder, previous thoughts of suicide, impulsive disorders, a parent that died from suicide, post-traumatic stress disorder, panic disorder, anorexia nervosa, adjustment disorder, obsessive-compulsive disorder, and any mood disorder), and a complete blood count. The only exclusion criteria was insufficient demographic data collected.

We also created a control group for comparison. From each year, by using a randomization algorithm, we selected the same number of patients aged 11–18 who presented to our pediatric department because of other etiologies (psychiatric and non-psychiatric). We used the same inclusion and exclusion criteria and collected the same information as in the attempted suicide group. We collected a total of 82 cases. The only characteristic that was not random for the control group was the gender of the patient, which we matched exactly to the gender of the attempted suicide group. Gender difference is known to influence suicide attempt chances [3] and we did not want this to cause bias in our results.

The primary objective was to characterize the main traits of adolescents who attempted suicide and presented to our pediatric emergency department. The secondary objective was to utilize this information to develop a neural network model capable of identifying adolescents at risk, thereby enabling early identification and the provision of preventive psychological interventions. Patient data were extracted from hospital medical records and anonymized prior to analysis. Categorical variables were compared between groups using chi-square or Fisher's exact tests, and continuous variables using the Mann-Whitney or *t*-test. Statistical analyses were performed using IBM Statistical Package for the Social Sciences statistics software, version 22 (SPSS, IBM Corp, Armonk, NY, USA). Two-sided significance level of 0.05 and 95% confidence intervals (95%CI) for parametric tests.

To develop the neural network model, we selected key variables that significantly differentiated the groups. A linear regression model was initially tested but performed poorly ($R^2 = 0.04$), indicating minimal predictive value. We then implemented a nonlinear neural network with three fully connected layers: 12 ReLU-activated nodes in the first layer, 8 ReLU-activated nodes in the second, and a sigmoid-activated output node producing a probability of suicide attempt (0 = low, 1 = high).

Data preprocessing and model development were performed using the Python programming language, employing libraries such as *SciPy*, *scikit-learn*, *NumPy*, and *pandas*. The neural network was implemented using *TensorFlow* and *Keras*.

To better reflect real-world population characteristics, we applied class weighting to account for the low prevalence of adolescent suicide attempts in Israel (0.16%) [9], penalizing misclassification of the minority class more heavily. Gender distribution was also balanced to 50% male and 50% female. The dataset was split into 80% training and 20% testing sets, with model performance evaluated on the test set to estimate predictive accuracy.

The trial was performed in accordance with the Declaration of Helsinki. The trial protocol was approved by the local medical ethics institutional review board.

RESULTS

We found that a significantly higher proportion of adolescents who attempted suicide were living outside their original home compared to those in the control group

(25.6% [21/82] vs. 4.88% [4/82]; odds ratio [OR] 6.710; $P = 0.000168$).

With regard to ethnicity, we compared the proportion of Ashkenazi vs. non-Ashkenazi ethnicity in both the control and suicide attempt group and found that there was an increase in the number of non-Ashkenazi in the suicide attempt group but the difference in proportion was not statistically significant as can be seen in Table 1 ($P = 0.0742$, 95%CI -0.0381–0.257 for proportional difference).

We also compared the number of patients whose parents were unmarried. In the suicide attempt group, we found statistically significant higher proportion of unmarried parents compared to the control group, with 45/82 (54.88%) in the suicide attempt group compared to 1/82 (1.22%) in the control group (OR 98.513, $P = 1.87 \times 10^{-16}$). Regarding age differences between groups, we found a modest but statistically significant elevation in the average age of the suicide attempt group. The mean age in the suicide attempt group was 15.56 years, compared to 14.53 years in the control group, resulting in a mean difference of 1.03 years (95%CI 0.477–1.583; $P = 0.000131$).

We also analyzed blood samples, specifically comparing hemoglobin levels between the two groups. The mean hemoglobin level in the suicide attempt group was significantly higher at 12.89 g/dl, compared to 11.64 gr/dl in the control group. This value represents a mean difference of 1.25 gr/dl (95%CI 0.689–1.81; $P = 6.30 \times 10^{-6}$).

The mean corpuscular volume (MCV) was also significantly higher in the suicide attempt group, with a mean of 85.218 fl compared to 79.38 fl in the control group, resulting in a mean difference of 5.84 fl (95%CI 3.609–8.066; $P = 0.0141$).

We also examined the psychiatric history of participants and found a significantly higher prevalence of prior psychiatric diagnoses in the suicide attempt group. Specifically, 60 of 82 individuals (73.17%) in the suicide attempt group had at least one psychiatric diagnosis compared to only 3 of 82 individuals (3.66%) in the control group (OR 71.818, $P = 2.593 \times 10^{-22}$). The results of the difference in characteristics in the groups are summarized in Table 1.

As anticipated, we observed a high proportion of females in the suicide attempt group, with 76 of 82 cases (92.7%) involving females. To assess the statistical significance of this finding, we compared the proportion of females in the suicide attempt group to the expected proportion in the general adolescent population (approximately 50%). Using the same number of females in both the control and suicide attempt groups for comparison, we found that the proportion of females in the suicide group was significantly higher than expected (OR 12.67, $P = 0.0502$). In addition, we saw an increase in the number of cases of suicide attempts in later years of the study. We compared the number of cases in 2015 compared to 2021. We found that there were four cases in 2015 compared to 17 cases in 2021 (OR 4.408, $P = 0.00321$).

The neural network model we created following these results can be found in our GitHub page [10] (The model is in a json file and the weights are in the .h5 file). The model achieved an accuracy of 99.85% on the testing set. Table 2 presents the correlation matrix for variables used in the neural network model. Most correlations were low, indicating minimal collinearity and supporting the inclusion of all variables for their potential independent contribution. The strongest correlations were between psychiatric diagnosis and unmarried parents (r = 0.582) and psychiatric diagnosis and living outside the home (r = 0.546), suggesting possible shared psychosocial or environmental factors. The GitHub page includes a detailed explanation of how to load the neural network model to a python environment. The needed files are on the GitHub page as well [10].

Table 1. Summary of the results characterizing the differences between the groups

	Suicide attempt	Control group	Statistics
Living outside home	21/82 (25.6%)	4/82 (4.88%)	OR 6.710, $P = 0.000168$
Ethnic: not Ashkenazi	36/82 (44%)	27/82 (32.92%)	$P = 0.0742$, 95%CI -0.0381–0.257 for proportional difference
Unmarried parents	45/82 (54.88%)	1/82 (1.22%)	OR 98.513, $P = 1.87 \times 10\text{-}16$
Mean age in years	15.56	14.53	95%CI 0.477–1.583, $P = 0.000131$
Mean hemoglobin, gr/dl	12.89	11.64	95%CI 0.689–1.81, $P = 6.30 \times 10^{-6}$
Mean MCV, fl	85.218	79.38	95%CI 3.609–8.066, $P = 0.0141$
Psychiatric background	60/82 (73.17%)	3/82 (3.66%)	OR 71.818, $P = 2.593 \times 10\text{-}22$

95%CI = 95% confidence interval, MCV = mean corpuscular volume

Table 2. Correlation matrix for the variables that have chosen for building the Neural Network model

	Age	Psychiatric diagnosis	Unmarried parents	Live outside home	Gender
Age	1	0.112334	0.14092	0.117961	0.001066
Psychiatric diagnosis	0.112334	1	0.582319	0.54566	0.108767
Unmarried parents	0.14092	0.582319	1	0.452986	0.143195
Live outside home	0.117961	0.54566	0.452986	1	0.17439
Gender	0.001066	0.108767	0.143195	0.127439	1

DISCUSSION

As the results show, the most prominent traits associated with an increased risk of suicide attempts among patients were a previous psychiatric diagnosis (including prior suicide attempts or suicidal ideation), OR 71, and the marital status of the parents. Specifically, having unmarried parents was associated with OR 98 for suicide attempts in their children. These two characteristics were the strongest predictors, consistent with existing literature [2].

Mean hemoglobin and MCV levels were significantly higher in the suicide attempt group compared to controls ($P = 6.30 \times 10^{-6}$ and $P = 0.014$, respectively). Prior studies have linked depression and suicide attempts to changes in white blood cells and platelets, such as elevated neutrophils and reduced platelet-to-lymphocyte ratios [11,12]. Furthermore, contrary to our findings, anemia has been associated with late-life depression and suicide attempts [13]. The higher hemoglobin levels observed in our adolescents are intriguing and warrant further investigation in larger studies.

It is noteworthy that there was a statistically significant increase in the number of suicide attempts over the course of the study, from 4 cases in 2015 to 17 cases by 2021. We hypothesize that the coronavirus disease 2019 pandemic, known for causing isolation, may have contributed to a decline in mood and an increased risk of suicide attempts as indicated by the high odds ratio for psychiatric illness in our findings.

Regarding our model, with neural networks increasingly applied in medicine [14], we aimed to develop a proof-of-concept tool for clinical decision support. Using routinely collected variables our model achieved a high discriminatory ability (accuracy 99.85%) in distinguishing adolescents with suicide attempts from matched controls. In practice, such a tool could be integrated into electronic medical records to flag high-risk adolescents based on subtle patterns, prompting earlier psychiatric evaluation or social support interventions.

However, because suicide attempts are rare and our sample is relatively small, there is concern about overfitting to our hospital's data. A model frequently predicting *no attempt* could still appear accurate given the low incidence; therefore, results should be interpreted cautiously. The correlation matrix showed the strongest associations for psychiatric illness, unmarried parental status, and living outside the home (r = 0.4–0.6), indicating possible interdependence. Future studies with larger, more diverse datasets are needed to build complementary models and enhance robustness.

Authors of a recent study developed an artificial intelligence model predicting suicide attempts in individuals older than 15 years, using more than 18,000 cases. The model achieved 38% sensitivity for males (using logistic regression) and 47% for females (using a neural network) [15]. We think that focusing on a narrower age range could yield greater predictive accuracy, given sufficient training data.

Acknowledging our analysis's limitations is important. The sample size in each group was relatively small (n=82), which limited the use of parametric testing for some analyses and led to the power of the neural network being very weak. Due to the insufficient sample size for certain assumptions, we employed non-parametric methods, including Fisher's exact test, to ensure appropriate statistical evaluation. In addition, we grouped all psychiatric diagnoses, limiting assessment of individual impacts, although literature highlights varying risks across specific diagnoses [8].

Another limitation was the lack of data on education, activities, and sexuality/LGBTQ status of patients, despite their importance as risk factors [16,17]. Consequently, these variables were not incorporated into our model. Gender, although potentially predictive, was not directly evaluated due to our equal male/female study design. Instead, we compared the female proportion to the general population (0.5). Future studies should include these variables as an independent variable in predictive models.

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That is what learning is. You suddenly understand something you've understood all your life, but in a new way.

Doris Lessing (1919–2013), British novelist poet, playwright, Nobel laureate

Capsule

A short-acting psychedelic intervention for major depressive disorder

Major depressive disorder (MDD) is a leading cause of disability worldwide, yet many patients have inadequate responses to current treatments. Dimethyltryptamine (DMT), a serotonergic psychedelic with rapid onset and short duration, shows promise as a potential antidepressant (AD), although clinical evidence in MDD remains limited. **Erritzoe** and co-authors conducted a phase IIa, double-blind, placebo-controlled, randomized clinical trial to evaluate the efficacy and safety of intravenous DMT (SPL026; DMT fumarate) in adults with moderate-to-severe MDD. Participants received a single 21.5-mg dose of DMT or placebo infused over 10 min, along with supportive psychotherapeutic support, followed by a 2-week assessment. A subsequent open-label phase offered all participants a second DMT dose. The primary outcome was the change in Montgomery–Åsberg Depression Rating Scale (MADRS) at 2 weeks. Secondary outcomes included response (≥ 50% reduction in MADRS score) and remission (MADRS ≤ 10). A total of 34 participants were randomized, 17 to placebo–active and 17 to active–active. At 2 weeks, the DMT group showed a significantly greater reduction in MADRS score than placebo (mean difference = −7.35; 95%CI −13.62 to −1.08; $P = 0.023$). In the open-label phase, AD effects persisted up to 3 months, with no significant differences between those who received one versus two doses. Adverse events were mostly mild to moderate, commonly infusion site pain, nausea, and transient anxiety. No serious adverse events occurred. A single dose of DMT with psychotherapeutic support produced a rapid, significant reduction in depressive symptoms, sustained up to 3 months. The treatment was well-tolerated and safe.

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