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Investigating the Relationship Between Cadets' Mathematical and Professional Training in the Context of State Border Protection

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Abstract

Objective: *The study aims to assess the relationship between cadets' mathematical training and their achievement in a professionally oriented discipline disciplines using methods of mathematical statistics. Particular attention is given to examining the statistical association between examination results in Higher Mathematics and Communication and ACS.*

Theoretical Framework: *The study is grounded in the principles of mathematical statistics, with an emphasis on nonparametric correlation analysis, statistical hypothesis testing, and the assessment of statistical significance. Kendall's τ and Spearman's ρ rank correlation coefficients are used to evaluate the strength and direction of the relationship between cadets' performance in mathematical and professionally oriented disciplines. Mathematical training is considered a key component of professional education that contributes to the development of analytical thinking, information processing, and problem-solving skills. From this perspective, examining the relationship between mathematical and professional academic performance is of both scientific and practical relevance.*

Method: *The study analyzed the examination results of 16 cadets in Higher Mathematics and Communication and ACS. The relationship between the variables was assessed using Spearman's ρ and Kendall's τ rank correlation coefficients. The examination results were ranked, and the strength and direction of the association were evaluated independently using both methods. The application of two nonparametric correlation measures provided a comparative verification of the findings. Statistical significance was assessed by testing the corresponding null and alternative hypotheses at the selected significance level.*

Results and Discussion: *The statistical analysis revealed a positive rank correlation between cadets' examination results in Higher Mathematics and Communication and ACS. Cadets who achieved higher result in Higher Mathematics also tended to demonstrate better performance in Communication. The consistency of the results obtained using Spearman's and Kendall's methods confirms a positive statistical association between mathematical and professionally oriented academic performance within the sample. However, the observed correlation should not be interpreted as evidence of a direct causal relationship.*

Research Implications: *The findings can be used to assess the relationship between mathematical and professionally oriented disciplines in training future specialists in State Border protection. They provide a basis for considering mathematical training an integral component of comprehensive professional education. The proposed statistical approach can also be applied to objectively analyze academic performance and identify relationships between cadets' learning outcomes across different disciplines.*

Originality/Value: *The value of the study lies in the practical application of methods of mathematical statistics to examine the relationship between cadets' performance in mathematical and professionally oriented disciplines. The combined use of Spearman's ρ and Kendall's τprovides two complementary nonparametric assessments of the relationship and enables cross-validation of the statistical findings. The study offers a methodological basis for further investigation into the relationship between mathematical and professional training in the education of future State Border protection specialists.*

Keywords: *mathematical statistics, mathematical training, professional training, rank correlation, Spearman's ρ Kendall's τ, Higher Mathematics, Communication, cadets, State Border protection.*

1. Introduction

Improving the quality of training for future specialists in State Border protection is an important objective of the military education system. The increasing complexity of operational activities, the growing volume of information, and the widespread use of technical systems require cadets to develop analytical thinking skills, process quantitative data, and make well-founded decisions. Therefore, general scientific and specialized training should be considered interconnected components of an integrated educational system.

However, cadets' performance in general scientific and professionally oriented disciplines is often assessed separately. The extent to which achievement in Higher Mathematics is associated with mastery of professional subjects is rarely evaluated using quantitative evidence. Consequently, although interdisciplinary links are incorporated into educational programs, their manifestation in actual learning outcomes remains insufficiently examined from a mathematical perspective. This creates a need for an objective, empirical assessment of these connections.

This issue is particularly relevant when examining the link between Higher Mathematics and professionally oriented technical courses. Mathematics fosters logical analysis, data processing, and applied problem-solving skills. The study of Communication and ACS, in turn, requires an understanding of technical information, quantitative reasoning, and a systematic approach to professional tasks. Although both fields share common cognitive foundations, theoretical assumptions alone are insufficient to establish whether their learning outcomes are practically connected.

Accordingly, the research problem is formulated as follows: Is there a statistically significant association between cadets' examination results in Higher Mathematics and Communication and ACS, and, if so, what are its direction and strength?

The relevance of the study lies in addressing this question using empirical data and rigorous statistical methodology. A quantitative evaluation of this interdisciplinary relationship contributes to a more objective analysis of learning outcomes, helps identify interdisciplinary synergy, and justifies the role of exact sciences in comprehensive military education.

To achieve this, nonparametric statistical methods were applied to the examination results of 16 cadets. In particular, Spearman's ρ and Kendall's τ_b rank correlation coefficients were used to determine the direction and strength of the association, while the concurrent use of both measures ensured cross-verification. Statistical hypothesis testing was subsequently performed to determine the significance of the findings.

The aim of the study is to evaluate the direction, strength, and statistical significance of the relationship between cadets' examination results in Higher Mathematics and Communication and ACS using Spearman's ρ and Kendall's τ_b coefficients.

The study is expected to provide an objective assessment of interdisciplinary relationships and to contribute to a clearer understanding of the role of Higher Mathematics in the training of future specialists in State Border protection. It should be emphasized, however, that correlation analysis identifies statistical associations between variables and does not imply a direct causal relationship.

2. Analysis Of Recent Studies and Publications

The professional orientation of mathematical training, the integration of mathematical knowledge with future career activities, and its role in developing cadets' core competencies have been extensively examined by both domestic and international researchers. Existing studies indicate that, within military education, mathematical instruction is regarded not only as a foundational discipline but also as a means of developing analytical, logical, and modeling skills required for solving specialized tasks.

N.M. Igoshina investigated the importance of mathematical education in developing the professional competence of military institute cadets [1]. The author emphasized the role of exact sciences in the formation of vocational and military-technical skills, highlighting the importance of quantitative methods for mastering specialized disciplines. This work provides a solid theoretical basis for understanding the interdisciplinary relationship between mathematical and specialized training.

I.N. Radaeva and I.V. Enekova examined contemporary issues related to teaching mathematics in military higher education institutions [2]. Their study focused on the practical orientation of curriculum design, the use of applied mathematical problems and simulation modeling, and the enhancement of student capabilities. The authors emphasized the need to align the content of mathematical education with the specific requirements of future operational activities.

B.M. Tursunov and R.M. Nauryzbayeva investigated the professional orientation of Higher Mathematics in relation to State Border protection tasks [3]. The authors proposed the integration of professionally oriented problems involving qualitative and quantitative assessment of border security effectiveness during group classes. This approach successfully links theoretical principles with future field operations and contributes to the development of cadets' ability to evaluate and analyze service-related challenges.

Modern approaches to profession-oriented mathematics education in military academies were examined by O. Fursenko, N. Chernovol, and H. Bobrytska. The authors explored the application of mathematical combat models in classrooms and considered mathematical modeling a key means of linking theoretical frameworks with military tasks. Their findings demonstrate the importance of adapting instructional methods to the specific requirements of tactical operations [4].

I.Y. Rakhmonov investigated the role of mathematics in developing intuitive competence among cadets of military educational institutions. The study emphasized that systematic problem solving contributes to the development of cadets' abilities to analyze complex information, identify patterns, and make well-founded decisions. Mathematical thinking is therefore considered an important cognitive component of future officers' overall preparation [5].

Recent research also reflects a growing interest in methodological and digital approaches to improving instructional quality. The integration of applied problems with advanced modeling, problem-based learning, and digital educational technologies expands opportunities for utilizing exact sciences in field-specific situations. These developments demonstrate an ongoing tendency to adapt the content and methods of science education to the shifting requirements of military service.

Overall, previous studies have established important theoretical and methodological foundations for understanding the role of mathematical training in the development of vocational skills, analytical reasoning, simulation modeling, and the ability to solve applied problems. However, the reviewed literature has primarily addressed these relationships from pedagogical, methodological, and applied perspectives. The quantitative statistical relationship between cadets' actual examination results in Higher Mathematics and their performance in professionally oriented disciplines remains insufficiently investigated.

The present study addresses this literature gap by examining the actual examination scores of 16 cadets in Higher Mathematics and Communication and ACS. The strength and direction of the relationship between the two sets of academic metrics are assessed using two nonparametric statistical methods: Spearman's (ρ) and Kendall's (τ) rank correlation coefficients. The parallel application of these methods allows the empirical findings to be cross-verified and provides an additional assessment of the consistency of the identified relationship.

Thus, the contribution of the present study lies in extending previous research on the professional orientation of mathematical training through a rigorous quantitative analysis of empirical academic performance data. Rather than examining the relationship between foundational and professional training solely from a pedagogical or methodological perspective, this study evaluates their statistical association using cadets' actual examination results. The identified correlation is interpreted strictly as a statistical association and does not imply a direct causal relationship between mathematical and professional academic performance.

3. Theoretical Framework

The theoretical framework of this study is grounded in the principles of mathematical statistics, which enable the quantitative analysis of educational outcomes and the empirical identification of underlying patterns. This statistical approach facilitates the systematic structuring of academic data, the discovery of dependencies among quantitative variables, and the objective interpretation of results based on rigorous analytical criteria.

Within the educational process, examination results serve as a primary quantitative metric characterizing students' mastery of a given curriculum. From this perspective, a comparative evaluation of cadets' academic achievement in Higher Mathematics and professionally oriented disciplines helps uncover potential associations between core performance metrics. Investigating these links provides a theoretical basis for viewing mathematical proficiency and specialized expertise not as isolated parameters, but as interrelated components of an integrated training system for future specialists.

A core element of the proposed theoretical model is correlation analysis, which is designed to measure the direction and strength of the statistical association between two variables. A positive correlation indicates that higher values in one indicator tend to correspond with higher values in the other, whereas a negative correlation demonstrates an inverse relationship. Crucially, the presence of a statistical correlation identifies mathematical dependencies within the dataset but does not imply a direct cause-and-effect mechanism.

When working with a limited sample size where strict assumptions regarding a normal data distribution cannot be guaranteed, the application of nonparametric statistical methods becomes necessary. These techniques assess the monotonic relationship between variables by transforming raw numerical scores into ordinal positions, known as ranks.

The mathematical foundation for this measurement relies on Spearman's (ρ) and Kendall's (τ) rank correlation coefficients. Spearman's ρ coefficient measures the strength and direction of the monotonic association based on the squared differences between the ranks of paired observations, utilizing average ranks in the presence of tied data points.

Conversely, Kendall's (τ) coefficient operates on the principle of pairwise comparisons across all possible observations. In this framework, pairs are classified as concordant or discordant depending on their relative ordering. To accommodate identical values within the dataset, the study utilizes Kendall's (τ_b) coefficient, which explicitly adjusts the mathematical formula to account for tied ranks, ensuring greater precision.

While Spearman's and Kendall's (τ_b) coefficients evaluate the same overarching statistical relationship, they do so based on fundamentally distinct mathematical logic: the former focuses on rank distance, whereas the latter evaluates relative ordering probabilities. Consequently, the concurrent application of both instruments allows the researcher to analyze the empirical data from complementary statistical angles and cross-validate the consistency of the final academic conclusions.

In summary, mathematical statistics offers a robust theoretical framework for investigating the continuity between cadets' foundational and professional training indicators. The combined deployment of correlation analysis alongside Spearman's (ρ) and Kendall's (τ) rank coefficients provides an objective, scientifically sound methodology to gauge the strength of these academic connections and interpret the findings with statistical validity.

4. Research Methodology

The research methodology is based on nonparametric methods of mathematical statistics aimed at identifying the relationship between cadets' mathematical and professional training outcomes. The empirical dataset consists of the examination results of 16 cadets from Training Border Post No. 1 during the 2023/2024 academic year in the disciplines Higher Mathematics and Communication and ACSs and Automated Control Systems (ACS).

The primary objective of this analysis is to determine the strength and direction of the association between academic performance in these two subjects. Within this framework, variable X represents the examination scores in Higher Mathematics, while variable Y denotes the scores in Communications and ACS. The paired performance metrics for each cadet were systematically organized for subsequent computation, with the baseline empirical data presented in Table 1.

Given the limited sample size $n = 16$ and to avoid strict, potentially invalid assumptions regarding a normal data distribution, nonparametric rank correlation methods were selected. The association between the two variables was evaluated utilizing Spearman's rank correlation coefficient ρ and Kendall's rank correlation coefficient τ_b.

For the Spearman correlation analysis, the original examination scores were converted into ordinal positions, allowing the measurement of the monotonic relationship between the variables based on rank correspondence. Conversely, Kendall's coefficient served as a complementary measure of ordinal association. Operating on the principle of pairwise comparisons, this method classifies observations as concordant or discordant according to their relative ordering.

The concurrent application of both Spearman's ρ and Kendall's (τ_b) coefficients facilitates a comprehensive comparison of the results obtained via distinct rank-based approaches. Agreement in both direction and statistical conclusions between the two methods serves as cross-validation, confirming the consistency of the identified association within the analyzed sample.

To evaluate the statistical significance of the correlation, the following null H_0 and alternative H_1 hypotheses were formulated:

H_0: There is no statistically significant rank correlation between cadets' examination results in Higher Mathematics and Communication and ACSs and ACS ($\rho = 0$; $\tau_b = 0$).
H_1: There is a statistically significant rank correlation between cadets' examination results in Higher Mathematics and Communication and ACSs and ACS ($\rho \neq 0$; $\tau_b \neq 0$).
Statistical decisions were evaluated at a significance level of α= 0,05.
These correlation methods rely on probabilistic models that describe variation patterns within the population from which the sample was drawn. Beyond the numerical assessment, a visual examination of the scatter plot (correlation field) was utilized to identify the structural form of the relationship, determining whether the observed association exhibits a linear or nonlinear trend.

At the final stage of the analysis, the outputs of both coefficients were systematically compared regarding their direction, strength, and statistical significance. The findings were interpreted strictly as a statistical association between cadets' mathematical and professional outcomes, without implying any direct causal mechanism between the variables under investigation.

Table 1. Examination Results in Higher Mathematics and Communication and ACSs and ACS

Cadet No. in the Register	Higher Mathematics Examination Result (X)	Communications and ACS Examination Result (Y)	**Cadet No. in the Register**	Higher Mathematics Examination Result (X)	Communications and ACS Examination Result (Y)
1	71	90	9	54	72
2	99	92	10	95	93
3	76	85	11	52	70
4	60	84	12	79	90
5	67	90	13	84	90
6	67	90	14	64	81
7	62	84	15	58	75
8	66	79	16	72	82

To address the research objective, Spearman's rank correlation coefficient $\rho$is used to determine the strength and direction of the correlation between the two variables. This statistical metric is a universal measure that can be applied to quantitatively measured or ranked data. Developed by C. Spearman, this nonparametric method for assessing intervariable relationships eliminates the need for prior assumptions regarding the distribution of the investigated characteristics within the population. The coefficient effectively makes it possible to determine the direction and strength of the relationship between ordinal variables, which, in this study, are represented by the ranks assigned to the academic parameters being compared.

One of the main conditions for applying this rank correlation technique is fully satisfied in this study: the number of observations for the compared variables X and Y is strictly equal $n = 16$.

To assess the significance of this metric, the statistical hypotheses are formulated as follows:

- H_0: $\rho = 0$ (The rank correlation between variables X and Y does not differ statistically significantly from zero).

- H_1: $\rho \neq 0$ (The rank correlation between variables X and Y differs statistically significantly from zero).

To determine the empirical correlation between variables X and Y, the original data are ranked separately for each variable. During the ranking procedure, the smallest numerical value is assigned the lowest rank, while the largest value is assigned the highest rank. If several observations have identical values, they are allocated the average of the corresponding rank positions.

Since some values were identical during the ranking procedure, the corresponding average ranks were assigned. To verify the correctness of the ranking, the sums of the rank columns corresponding to variables X and Y in Table 2 were calculated. The resulting sum of the ranks for each subject equals exactly 136, confirming that the ranking procedure was performed correctly (Table 2).

Table 2. Ranks of Examination Results by Discipline

Cadet No. in the Register	Ranks of Higher Mathematics Examination Results	Ranks of Communications and ACS Examination Results	**Cadet No. in the Register**	Ranks of Higher Mathematics Examination Results	Ranks of Communications and ACS Examination Results
1	10	12	9	2	1,5
2	16	15	10	15	16
3	12	9	11	1	5,5
4	4	7,5	12	13	12
5	8,5	12	13	14	12
6	8,5	12	14	6	3,5
7	5	7,5	15	3	3,5
8	7	1,5	16	11	5,5

We verified the accuracy of the calculation using the formula. The verification yielded the following results:

$$\frac{N(N+1)}{2} = \frac{16 \cdot 17}{2} = 136.$$

Formula for calculating Spearman's rank correlation coefficient in the presence of tied ranks [6]:

$$\rho = 1 - 6 \cdot \frac{\sum d^2 + T_x + T_y}{n \cdot (n^2 - 1)}, \qquad (1)$$

where n is the sample size; d is the difference between the ranks of variables X and Y for each cadet; $T_x = \frac{\sum(x^3 - x)}{12}$, where x is the number of values in each group of tied ranks in the rank series X; and $T_y = \frac{\sum(y^3 - y)}{12}$, where y is the number of values in each group of tied ranks in the rank series Y.

Based on the ranking results of the variables presented in Table 3, the necessary calculations were performed using Microsoft Excel.

Table 3. Calculations performed using Microsoft Excel

Cadet No. in the Register	Ranks of Higher Mathematics Examination Results	Ranks of Communications and ACS Examination Results	d	d^2
1	10	12	-2	4
2	16	15	1	1
3	12	9	3	9
4	4	7,5	-3,5	12,25
5	8,5	12	-3,5	12,25
6	8,5	12	-3,5	12,25
7	5	7,5	-2,5	6,25
8	7	1,5	5,5	30,25
9	2	1,5	0,5	0,25
10	15	16	-1	1
11	1	5,5	-4,5	20,25
12	13	12	1	1
13	14	12	2	4
14	6	3,5	2,5	6,25
15	3	3,5	-0,5	0,25
16	11	5,5	5,5	30,25
	136	136		150,5

In the second rank series, there is one group consisting of two tied values, while in the third rank series, there is one group of five tied values and four groups of two tied values each. Therefore, the correction terms accounting for tied ranks are determined as follows:

$$T_x = \frac{2^3 - 2}{12} = 0{,}5;\ \ T_y = \frac{5^3 - 5}{12} = 10;\ \ T_y = 4 \cdot \frac{2^3 - 2}{12} = 2$$

Before proceeding with the analysis, two main research questions must be addressed: first, to determine whether a statistical relationship exists between the ranks assigned to the examination results in Higher Mathematics and Communication and ACSs and ACS; second, if such a relationship is identified, to assess its direction and strength.

Accounting for the appropriate corrections for tied ranks, Spearman's rank correlation coefficient is calculated. According to formula (1), the following result is obtained:

$$\rho = 1 - 6 \cdot \frac{150{,}5 + +0{,}5 + 10 + 2}{16 \cdot 255} = 0{,}76.$$

Since the sample size in the study is n = 16, we determine the critical values of Spearman's rank correlation coefficient using Table 4. For the significance level α = 0.01, we find the corresponding critical value of the Spearman's coefficient.

Table 4 – Critical values of Spearman's rank correlation coefficient [6, p. 49]

n	*α*		*n*	*α*		*n*	*α*	
	0,05	**0,01**		**0,05**	**0,01**		**0,05**	**0,01**
5	0,94	–	*17*	0,48	0,62	*29*	0,37	0,48
6	0,85	–	*18*	0,47	0,60	*30*	0,36	0,47
7	0,78	0,94	*19*	0,46	0,58	*31*	0,36	0,46
8	0,72	0,88	*20*	0,45	0,57	*32*	0,36	0,45
9	0,68	0,83	*21*	0,44	0,56	*33*	0,34	0,45
10	0,64	0,79	*22*	0,43	0,54	*34*	0,34	0,44
11	0,61	0,76	*23*	0,42	0,53	*35*	0,33	0,43
12	0,58	0,73	*24*	0,41	0,52	*36*	0,33	0,43
13	0,56	0,70	*25*	0,40	0,51	*37*	0,33	0,43
14	0,54	0,68	*26*	0,39	0,50	*38*	0,32	0,41
15	0,52	0,66	*27*	0,38	0,49	*39*	0,32	0,41
16	0,50	0,64	*28*	0,38	0,48	*40*	0,31	0,40

The calculated empirical value of Spearman's rank correlation coefficient was $\rho = 0{,}76$ for $n = 16$ and a significance level of $\alpha = 0.01$, the critical value of the coefficient is $\rho_{crit} = 0.64$.

$$0{,}76 = \rho < \rho_{\text{кр}} = 0{,}64.$$

Since the empirical value is higher than the critical value, the null hypothesis H_0 is rejected, and there is sufficient statistical evidence to support the alternative hypothesis $\mathbf{H_1}$. Thus, a statistically significant positive rank correlation was identified between the cadets' examination results in Higher Mathematics and Communication and ACS and Automated Control Systems at the significance level $\alpha = 0{,}01$.

The obtained result indicates that cadets who achieved higher examination results in Higher Mathematics also tended to achieve higher results in Communication and Automated **Control Systems**. This suggests the presence of a statistical association between the indicators of cadets' mathematical and professional training. However, the identified correlation does not demonstrate that higher performance in one discipline directly causes higher performance in the other. Therefore, the results should be interpreted as a **statistical association** between the two investigated indicators**.**

At the next stage of the study, the nature of the identified statistical relationship is assessed graphically. For this purpose, a correlation field, i.e., a scatter plo**t**, is constructed using the original values of variables X and Y**.** The experimental data are represented by the following coordinates:

(71; 90), (99; 92), (76; 85), (60; 84), (67; 90), (67; 90), (62; 84), (66; 79), (54; 72), (95; 93), (52; 70), (79; 90), (84; 90), (64; 81), (58; 75), (72; 82).

Here, *X* represents the examination results in Higher Mathematics**,** while Y represents the examination results in Communication and Automated Control Systems**.**

The scatter plot obtained by plotting the **(X, Y)** points on the coordinate plane visually indicates a positive relationship between the variables (Figure 2). The overall distribution of the points shows a tendency for **Y to increase as X increases**. To determine the specific form of this relationship and assess the suitability of a linear model, further **regression analysis** is required.

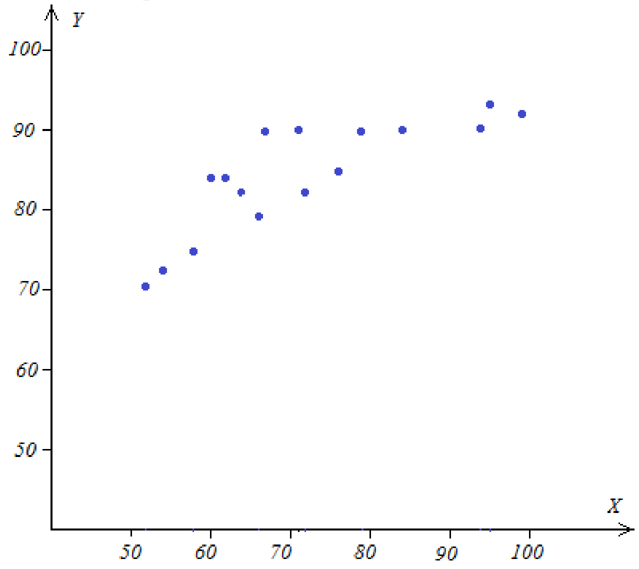

Figure 2. Scatter plot of the (X, Y) data points.

The parameters a and b of the linear regression equation are determined. For this purpose, the extremum condition of the least squares method is applied.

$$F(a,b) = \sum_{i=1}^{n} \left[y_i - \varphi(x_i, a, b) \right]^2 = \min$$

As a result of verifying the necessary extremum conditions, we obtain a system of normal equations that allows the unknown parameters a and b to be determined [7]:

$$\begin{cases} a\sum_{i=1}^{n} x_i^2 + b\sum_{i=1}^{n} x_i = b\sum_{i=1}^{n} x_i y_i \\ \quad a\sum_{i=1}^{n} x_i + bn = \sum_{i=1}^{n} y_i \end{cases} \tag{2}$$

The intermediate values required to construct the system of normal equations and calculate its parameters were determined using Microsoft Excel. The calculation results are presented in Table 5.

Table 5. Calculations Required for Constructing the System of Linear Equations

Cadet No. in the Register	Higher Mathematics Examination Result (X)	Communications and ACS Examination Result (Y)	x_i^2	$x_i y_i$
1	71	90	5041	6390
2	99	92	9801	9108
3	76	85	5776	6460
4	60	84	3600	5040
5	67	90	4489	6030
6	67	90	4489	6030
7	62	84	3844	5208
8	66	79	4356	5214
9	54	72	2916	3888
10	95	93	9025	8835
11	52	70	2704	3640

12	79	90	6241	7110
13	84	90	7056	7560
14	64	81	4096	5184
15	58	75	3364	4350
16	72	82	5184	5904
	$\sum_{i=1}^{16} x_i$ =1126	$\sum_{i=1}^{16} y_i$ =1347	$\sum_{i=1}^{16} x_i^2$ =81982	$\sum_{i=1}^{16} x_i y_i$ =95951

We construct the system of equations (2):

$$\begin{cases} 81982a + 1126b = 95951 \\ 1126a + 16b = 1347 \end{cases}$$

The parameter values are $= 0.42$ и $b = 54.5$.

Thus, the linear regression equation describing the relationship between the two random variables is as follows:

$$y = 0.42x + 54.5.$$

The graph of the resulting regression equation is shown in Figure 3.

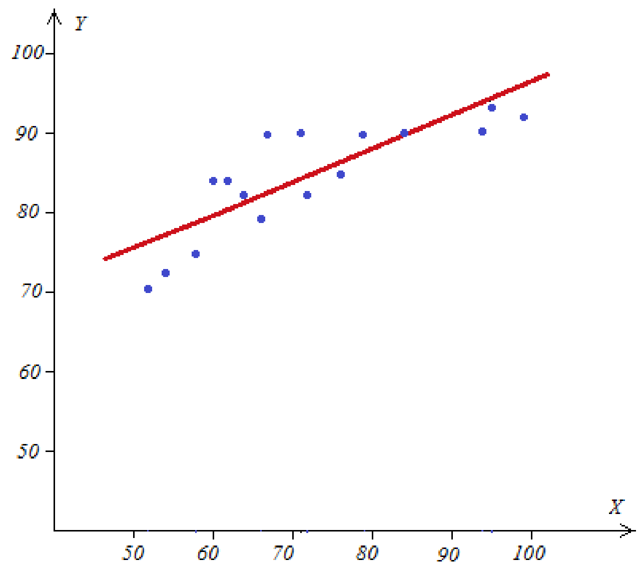

Figure 3. Graph of the linear regression function y = 0.42x + 54.5.

To additionally verify the robustness of the results obtained using Spearman's rank correlation coefficient, Kendall's τ rank correlation coefficient was applied to the same baseline data. This method allows for assessing the ordinal consistency of observations across two variables based on a comparison of concordant and discordant pairs.

The statistical hypotheses for Kendall's method were formulated as follows:

- H_0:: There is no statistically significant rank correlation between the examination results in Higher Mathematics and Communication and ACS and Automated Control Systems (i.e., $\tau = 0$).

- H_1: There is a statistically significant rank correlation between the examination results in Higher Mathematics and Communication and ACS and Automated Control Systems (i.e., $\tau \neq 0$)).

For tied ranks, Kendall's τ formula is given as follow [8]:

$$\tau_b = \frac{P-Q}{\sqrt{P+Q+T}\sqrt{P+Q+U}}, \qquad (3)$$

Where;
- P is the number of concordant pairs;

- Q is the number of discordant pairs;

- T is the number of tied values for variable X (ties in X);

- U is the number of tied values for variable Y (ties in Y).
To test the null hypothesis H_0: τ_b=0 (the Kendall rank correlation coefficient is equal to zero) at a given significance level α against the alternative hypothesis H_1: $\tau_b \neq 0$, the critical value of the test statistic is calculated as follows:

$$T_{\text{critical point.}} = Z_{cr}\sqrt{\frac{2(2n+5)}{9n(n-1)}}, \qquad (4)$$

where n is the sample size, Z_{cr} is the critical value for the two-tailed test, which is determined from the Laplace (standard normal) distribution table according to the following relationship:

$$\Phi(Z_{kr}) = (1-\alpha)/2 \qquad (5)$$

If $|\tau| < T_{\text{critical point}}$, there is no reason to reject the null hypothesis. Therefore, the rank correlation between the variables is not statistically significant.

If $|\tau| > T_{\text{critical point}}$, the null hypothesis is rejected. In this case, it is assumed that a rank correlation relationship exists between the variables.

For 16 observations, the total number of all possible pairs is: $\frac{16(16-1)}{2} = 120$.

The pairs are classified according to the following rules: if $(x_i - x_j)(y_i - y_j) > 0$, the pair is concordant (P); if $(x_i - x_j)(y_i - y_j) < 0$, the pair is discordant (Q); if $x_i = x_j$ but $y_i \neq y_j$, there is a tie in X (T); if $y_i = y_j$ but $x_i \neq x_j$, there is a tie in Y (U); and if $x_i = x_j$ and $y_i = y_j$, a complete tie occurs.

1. Pairs (1, k), where k = 2,…,16

$$X_1 = 71, Y_1 = 90.$$

(1,2): 71 < 99 and 90 < 92 → concordant → +1 P

(1,3): 71 < 76 and 90 > 85 → discordant → +1 Q

(1,4): 71 > 60 and 90 > 84 → concordant → +1 P

(1,5): 71 > 67 and 90 = 90 → tie in Y → +1 U

(1,6): 71 > 67 and 90 = 90 → tie in Y → +1 U

(1,7): 71 > 62 and 90 > 84 → concordant → +1 P

(1,8): 71 > 66 and 90 > 79 → concordant → +1 P

(1,9): 71 > 54 and 90 > 72 → concordant → +1 P

(1,10): 71 < 95 and 90 < 93 → concordant → +1 P

(1,11): 71 > 52 and 90 > 70 → concordant → +1 P

(1,12): 71 < 79 and 90 = 90 → tie in Y → +1 U

(1,13): 71 < 84 and 90 = 90 → tie in Y → +1 U

(1,14): 71 > 64 and 90 > 81 → concordant → +1 P

(1,15): 71 > 58 and 90 > 75 → concordant → +1 P

(1,16): 71 < 72 and 90 > 82 → discordant → +1 Q

Result: P = 9, Q = 2, T = 0, U = 4.

2. Pairs (2, k), where k = 3,…,16

$$X_2 = 99, Y_2 = 92$$

(2,3): 99 > 76 and 92 > 85 → concordant → +1 P

(2,4): 99 > 60 and 92 > 84 → concordant → +1 P

(2,5): 99 > 67 and 92 > 90 → concordant → +1 P

(2,6): 99 > 67 and 92 > 90 → concordant → +1 P

(2,7): 99 > 62 and 92 > 84 → concordant → +1 P

(2,8): 99 > 66 and 92 > 79 → concordant → +1 P

(2,9): 99 > 54 and 92 > 72 → concordant → +1 P

(2,10): 99 > 95 and 92 < 93 → discordant → +1 Q

(2,11): 99 > 52 and 92 > 70 → concordant → +1 P

(2,12): 99 > 79 and 92 > 90 → concordant → +1 P

(2,13): 99 > 84 and 92 > 90 → concordant → +1 P

(2,14): 99 > 64 and 92 > 81 → concordant → +1 P

(2,15): 99 > 58 and 92 > 75 → concordant → +1 P

(2,16): 99 > 72 and 92 > 82 → concordant → +1 P

Result: P = 13, Q = 1, T = 0, U = 0.

3. Pairs (3, k), where k = 4,…,16

$$X_3 = 76, Y_3 = 85$$

(3,4): 76 > 60 and 85 > 84 → concordant → +1 P

(3,5): 76 > 67 and 85 < 90 → discordant → +1 Q

(3,6): 76 > 67 and 85 < 90 → discordant → +1 Q

(3,7): 76 > 62 and 85 > 84 → concordant → +1 P

(3,8): 76 > 66 and 85 > 79 → concordant → +1 P

(3,9): 76 > 54 and 85 > 72 → concordant → +1 P

(3,10): 76 < 95 and 85 < 93 → concordant → +1 P

(3,11): 76 > 52 and 85 > 70 → concordant → +1 P

(3,12): 76 < 79 and 85 < 90 → concordant → +1 P

(3,13): 76 < 84 and 85 < 90 → concordant → +1 P

(3,14): 76 > 64 and 85 > 81 → concordant → +1 P

(3,15): 76 > 58 and 85 > 75 → concordant → +1 P

(3,16): 76 > 72 and 85 > 82 → concordant → +1 P

The remaining pairs are calculated in a similar manner. Results of the comparison of all 120 pairs:

P = 95 – concordant pairs;

Q = 14 – discordant pairs;

T = 0 – pairs tied only on variable X;

U = 10 – pairs tied only on variable Y;

B = 1 – pair completely tied on both variables X and Y.

We verify the total number of pairs:

95 + 14 + 0 + 10 + 1 = 120.

Thus, all 120 possible pairs were fully accounted for. The fact that the number of concordant pairs (P = 95) is considerably greater than the number of discordant pairs (Q = 14) indicates a positive rank association between the variables under investigation.

Let us calculate Kendall's τ coefficient using formula (3).

$$\tau_b = \frac{95 - 14}{\sqrt{95 + 14 + 0}\sqrt{95 + 14 + 10}} \approx 0{,}71.$$

At the significance level $\alpha = 0{,}05$, the test statistic value Z_{test} is determined using the Laplace function table from the equation (5).

$$\Phi(Z_{test}) = \frac{1-0{,}01}{2} = 0{,}495.$$

Which gives the critical value for the two-sided region as $Z_{test} = 2{,}576$.

Subsequently, to test the null hypothesis that Kendall's rank correlation coefficient $\tau = 0$ against the alternative hypothesis H_1: $\tau \neq 0$, the test statistic $T_{test.}$ is computed using formulas (4) and (3).

$$T_{test} = 2{,}576\sqrt{\frac{2(2\cdot 16+5)}{9\cdot 16(16-1)}} = 2{,}576\sqrt{\frac{74}{2160}} = 0{,}53$$

We have the inequality

$$0{,}71 = |\tau_b| > T_{test} = 0{,}53.$$

Therefore, the null hypothesis is rejected. In this case, it is concluded that there is a rank correlation between the variables. If rank correlation exists, this means that as the values of one variable increase (since $\tau > 0$), the rank of the second variable changes systematically; that is, the variable values change not randomly, but in a consistent manner.

The calculation of Kendall's rank correlation coefficient based on the examination results of 16 cadets yielded a value of $\tau_b = 0{,}71$.

The result obtained using Kendall's method is consistent with the conclusion based on Spearman's rank correlation coefficient. Spearman's coefficient was $\rho = 0.76$, while Kendall's coefficient was $\tau_b = 0{,}71$ Both coefficients indicate a positive and statistically significant rank correlatio**n** between the variables under investigation.

Thus, the combined application of the two nonparametric correlation methods demonstrates the consistency of the obtained results and supports the robustness of the statistical conclusion. Cadets who achieved higher results in Higher Mathematics generally tended to achieve higher results in Communication and Automated Control Systems as well. However, the identified statistical association does not imply that higher performance in one discipline directly causes higher performance in the other (Table 6).

Table 6. Comparison of results obtained using Spearman's and Kendall's methods

Method	Coefficient	Conclusion
Spearman	$\rho = 0.76$	Positive, statistically significant correlation
Kendall	$\tau = 0{,}71$	Positive, statistically significant correlation

5. Research Results

The examination results of 16 cadets in Higher Mathematics and Communication and ACS and Automated Control Systems (ACS) were analyzed using nonparametric statistical methods. The combined application of Spearman's and Kendall's rank correlation coefficients enabled a cross-validation of the consistency and robustness of the identified relationships.

The correlation analysis using Spearman's method revealed a strong positive rank correlation between the cadets' examination results in Higher Mathematics and Communication and ACS and ACS ($\rho = 0{,}76$). This indicates a robust positive association between the two variables under investigation.

To verify these findings, Kendall's rank correlation coefficient was applied to the same baseline data. A comparison of all 120 possible pairs for the 16 cadets identified 95 concordant pairs, 14 discordant pairs, 10 pairs tied on variable Y, and one pair completely tied on both variables X and Y. The calculated Kendall's coefficient was $\tau_b = 0{,}71$. Statistical significance testing confirmed that the identified relationship could not be explained by random variation, supporting the alternative hypothesis of a meaningful rank association.

6. Discussion

The empirical findings provide a quantitative framework for assessing the relationship between cadets' mathematical and professional training. The positive correlation identified by both Spearman's and Kendall's coefficients indicates that performance in Higher Mathematics and academic outcomes in Communication and ACS are significantly interrelated.

From a pedagogical perspective, mathematical training is primarily aimed at developing cadets' logical and analytical thinking, their ability to systematically organize and process information, analyze quantitative data, and solve problems algorithmically. These cognitive skills are directly applicable when mastering professionally oriented disciplines. From this perspective, the positive statistical association identified suggests that mathematical and professional training should not be viewed as isolated components, but rather as complementary elements of an integrated cadet education system.

Furthermore, the findings demonstrate the appropriateness of applying nonparametric methods of mathematical statistics to educational performance analysis. Given the limited sample size, rank correlation methods enable a reliable assessment of relationships between variables without imposing strict assumptions regarding their underlying distributions. Moreover, the combined deployment of these two statistical tools allowed for effective cross-validation of the conclusions reached.

Limitations of the study. Several constraints must be acknowledged when interpreting these results. The study was conducted using a relatively small sample of 16 cadets and relied on examination data from only two specific disciplines. In practice, cadets' academic performance is multifactorial and can be influenced by prior knowledge levels, learning motivation, individual cognitive abilities, class attendance, and other unmeasured variables. Consequently, the identified correlation must be interpreted strictly as a statistical association rather than a direct causal relationship.

7. Conclusion

This study established a statistically significant positive rank correlation between the examination results of 16 cadets in Higher Mathematics and Communication and ACS and ACS (ρ = 0,76; τ_b= 0,71). The statistical convergence of both nonparametric methods confirms the stability of the relationship within the investigated sample, demonstrating that higher achievements in fundamental mathematical training are associated with better academic outcomes in specialized disciplines.

The practical significance of this research lies in highlighting the need to enhance interdisciplinary connections across the curriculum. Actively incorporating professionally oriented applied problems, elements of mathematical modeling, and case studies based on real-world scenarios related to State Border protection into the Higher Mathematics syllabus can significantly improve cadets' capacity to operationalize mathematical knowledge when solving complex professional tasks.

Future research should focus on expanding the sample size, incorporating data from multiple training cohorts, and exploring the correlation between mathematical performance and a broader spectrum of specialized disciplines. Such expanded analyses will provide a more comprehensive framework for assessing the exact role of mathematical training in developing professional competencies and contribute to the scientifically grounded optimization of the educational process for future State Border protection specialists.

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