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Abstract

Background: Type 2 diabetes mellitus (T2DM) and prediabetes pose a growing public health challenge. Early detection and management are key to preventing complications and maintaining work capacity. In the defense sector, regular medical fitness assessments may facilitate early diagnosis, while strict occupational fitness standards could delay disease onset.

Objective: This study examines the diagnostic characteristics of carbohydrate metabolism disorders in defense sector employees and civilians, based on patient data from the North Pest Central Hospital - Military Hospital (ÉPC-HK) Diabetology Outpatient Clinic. It explores differences in age at diagnosis and detection circumstances between the two groups.

Methods: A retrospective cross-sectional study analyzed anonymized records of 4,820 T2DM or prediabetes patients (2019–2023). Statistical comparisons were made between defense employees (n=2,241) and civilians (n=2,579), focusing on age at diagnosis and detection circumstances.

Results: No significant difference in age at diagnosis was found ($p=0.264$), indicating career requirements alone may not delay disease onset. However, significantly more cases in the defense sector were detected through occupational screenings ($p<0.001$), while civilian cases were more often diagnosed due to symptoms or complications.

Conclusion: Regular medical screenings enhance early detection in the defense sector, underscoring the role of occupational health exams. This supports timely prevention and treatment. The five-year data period limits causal analysis, warranting future research on work conditions, lifestyle, demographics, and psychosocial factors.

Keywords: TYPE-2 DIABETES MELLITUS, PREDIABETES, MEDICAL FITNESS EXAMINATION, DIAGNOSIS OF CARBOHYDRATE METABOLISM DISORDER, SCREENING

Introduction

Based on the data from the International Diabetes Federation (*IDF*)[1], diabetes mellitus (*DM*) has reached epidemic proportions globally and has become one of the fastest-growing health challenges of the 21st century. For the global population aged 20–79 years, the prevalence[2] of diabetes has tripled from 2000 to 2021, and this trend is expected to continue. The number of patients in this age group could reach as many as 643 million by 2030 and 783 million by 2045. [1] Approximately 90% of cases involve type 2 diabetes mellitus (*T2DM, Type-2 Diabetes Mellitus*). In Hungary, based on an analysis conducted by the National Health Insurance Fund (*NEAK*), previously known as the National Health Insurance Fund Administration (*OEP*), the prevalence of T2DM in 2016 was 7.27% in the general population. [2] The actual number of patients is likely even higher due to undiagnosed cases; according to IDF data, the global number of undiagnosed individuals in 2021 was approximately 240 million. [1] Based on these findings, diabetes may have affected as many as one million individuals in Hungary in 2016. [3] In a previous study conducted on the staff of the Hungarian Defense Forces, a screening between 2004–2007 indicated a diabetes prevalence of 3.5%. [4] Encouraging trends have been observed, suggesting a decrease in the proportion of newly diagnosed cases in high-income countries, including Hungary, by over 70% between 2006 and 2017. [5]

T2DM predominantly occurs in middle-aged and older adults (as suggested by its previous names, such as adult-onset or maturity-onset diabetes). However, in recent decades, primarily due to lifestyle changes, its incidence[3] has also been increasing among younger populations. [6] [7]. The earlier it manifests, the greater its clinical significance, as it is associated with a poorer prognosis due to the more frequent occurrence of complications and a higher relative risk of mortality. [8] [9] [10]

The age of defense sector employees and the prevalence of T2DM within this population, along with other characteristics, make it one of the conditions where prevention could yield significant results for maintaining work capacity. The prevalence of T2DM in the 40–70 age

[1] The IDF is an international organization whose mission is to combat diabetes and coordinate efforts against it on a global scale.
[2] The proportion (prevalence) of individuals suffering from a specific disease within the total population
[3] The frequency of newly occurring cases within a specific time period.

group is also sharply increasing in Hungary, and individuals aged 40–60 represent the most active participants in the labor market. [2] Their health condition plays a crucial role in work capacity and performance. According to reports from the United States military health system, the prevalence of diabetes shows a rising trend primarily among those aged over 45. [11] In Hungary, changes introduced by the modification of Act CLXVII of 2011, effective as of January 1, 2013, concerning the elimination of early retirement pensions and benefits for early retirement in the armed forces and law enforcement, shifted the eligibility for preferential retirement above the age of 65. [12] As a result, the end of service has also moved beyond the age of 65. This is associated with a projected increase in the prevalence of chronic illnesses – including DM – among members of the armed forces.

The early diagnosis of DM is critically important, as timely and effective treatment can positively influence the progression of the disease, the development of complications, and the patient's quality of life. [13] [14] The development of T2DM is a prolonged process, with impaired secretion of insulin - the hormone primarily responsible for carbohydrate metabolism - preceding the progression to abnormally high blood sugar levels by several years. In addition to excess body weight, insulin resistance becomes more common, forcing insulin-producing cells into overactivity. As these cells' capacity to produce insulin begins to decline, postprandial blood sugar levels increase first, followed by fasting blood sugar levels later. Typical symptoms and complaints of diabetes may appear, such as increased thirst, dry mouth, frequent urination, vision disturbances, unexplained weight loss, slower wound healing, and, less commonly, confusion or coma. In such cases, laboratory tests are necessary to assess the state of carbohydrate metabolism. The diagnosis is guided by the currently valid clinical guidelines and can only be established based on blood sugar levels and, nowadays, haemoglobin-A1c (*HbA1c)* values determined from venous blood under laboratory conditions. [15] In the presence of typical signs, a single abnormal laboratory parameter is sufficient for diagnosis; however, in the absence of such signs, two abnormal values measured on separate occasion are required. Since T2DM is often asymptomatic, it is unfortunately common in everyday clinical practice for diabetes to be diagnosed only when managing an already developed complication.

If the fasting blood glucose level (measured at least 10 hours after the last caloric intake) is 7.0 mmol/L or higher, or the random glucose level (independent of meals) is 11.1 mmol/L or higher, the diagnosis of DM can be established. If the fasting blood glucose level is already elevated (above 6.0 mmol/L) but does not reach the diagnostic criteria for diabetes (7.0 mmol/L), an oral glucose tolerance test (*OGTT, Oral Glucose Tolerance Test*) should be performed to determine the stage of carbohydrate metabolism disorder. During this test, the individual consumes 75 g of glucose, and

blood samples are taken at specified times to measure serum glucose levels. If the test is conducted under the conditions outlined in the clinical protocol and according to the prescribed standards, the results can indicate not only DM but also prediabetic states, such as elevated fasting glucose levels (*IFG, Impaired Fasting Glucose*), reduced glucose tolerance (*IGT, Impaired Glucose Tolerance*), or the combined presence of both (*Table 1*).

In recent years, the determination of HbA1c levels using standard laboratory methods has also been utilized for establishing a diagnosis (*Table 1*). This parameter indicates the percentage of hemoglobin molecules—found in red blood cells and involved in the transport of oxygen and carbon dioxide—that are bound to glucose molecules. Due to the lifespan of red blood cells, this percentage reflects the average blood glucose levels over the past 90–120 days.

	Normal Carbohydrate Metabolism	**Prediabetes**			**DM Diabetes Mellitus**
		IFG Impaired Fasting Glucose	**IGT Impaired Glucose Tolerance**	**IFG and IGT together**	
OGTT "0 min" glucose level (mmol/L)	<6.0	6.1-6.9	<6.1	6.1-6.9	7.0≤
OGTT "120 min glucose level (mmol/L)	<7.8	<7.8	7.8-11.0	7.8-11.0	11.1≤

“HbA1c” level (%)	<5.6	5.7-6.4	6.5≤

Table 1: Diagnostic Criteria for Normal Glucose Tolerance and Carbohydrate Metabolism Disorders Based on OGTT Results and HbA1c Levels
Source: Report of a WHO/IDF Consultation [16]and ADA (2019)[17]

Screening is recommended for individuals at high risk of developing DM (aged 45 or older, overweight or obese, positive personal and family medical history, or practicing certain lifestyles) in accordance with applicable regulations. [18] This involves performing an OGTT as specified or determining the HbA1c level using standard laboratory methods. On a population level, targeted laboratory tests should be conducted based on the results of the FINDRISC (*Finnish Diabetes Risk Score*) risk-based questionnaire in smaller or larger cohorts. [15]

The professional career of armed forces personnel includes regular physical labor and medical fitness examinations. Both have a preventive effect on the development of diabetes. Regular medical check-ups enable the early detection of the disease. Based on this, it can be assumed that in their case, carbohydrate metabolism disorders may be diagnosed earlier, even in prediabetic states, compared to the civilian population, and that diabetes develops at a later age.

The North Pest Centre Hospital – Military Hospital (*ÉPC-HK*), and its predecessor, the Hungarian Defense Forces Medical Center (*MH-EK*), was established on July 1, 2007, through the merger of several institutions. [19] The specialized procedural protocols necessary for the provision of healthcare professional tasks and unique service obligations were developed based on unified criteria. The primary task of the institute became military healthcare support and services. However, following integration, the territorial care of the civilian population—primarily in the North Pest region—came increasingly to the forefront, representing the highest level of progression in certain medical fields. Over the years, several structural transformations have taken place; the most significant change occurred on January 1, 2023. On this date, the Military Hospital, which had been operating as part of MH-EK, was separated and placed under the authority of the Minister of the Interior and the National Hospital Directorate-General as a new healthcare provider under the name ÉPC–HK. Despite these changes, the eligibility framework remained intact along with its core

functions. Thus, the institute continues to provide healthcare, including diabetology care, for individuals residing in specific districts of Budapest and employees of the defense forces. [20]

Objective

In this publication, I aim to present the first segment of my findings related to the circumstances of carbohydrate metabolism disorder diagnostics and the presence of chronic macrovascular complications in patients managed at the ÉPC-HK Diabetology Outpatient Clinic for T2DM or prediabetes between January 1, 2019, and December 31, 2023. This study involves a retrospective analysis of the diagnostic characteristics, a comparison of data specific to defense sector employees and the civilian population, and their alignment with available literature or statistical data. The prevalence of macrovascular complications will be addressed in a subsequent publication.

Hypotheses

Hypothesis 1.: Among individuals attending the diabetology outpatient clinic for T2DM or prediabetes, diabetes develops at a later age in defense sector employees compared to the civilian population. Among individuals presenting at a diabetology outpatient clinic due to T2DM or prediabetes, carbohydrate metabolism disorders develop at a later age in defense sector workers compared to the civilian population.

Hypothesis 2.: In defense sector employees, T2DM or prediabetes is more frequently diagnosed during fitness-for-duty examinations and less often identified due to symptoms or the development of diabetes-related complications compared to the civilian population.

Methods

My study was conducted with the necessary prior research approvals (BM/26853-1/2024 from the Scientific and Research Ethics Committee of the Medical Research /*TUKEB*/ and EPCHK-RKEB-2024/11/06-2 from the Regional Research Ethics Committee /*RKEB*/). I analyzed the health data of individuals who attended the ÉPC-HK Diabetology Outpatient Clinic for diabetes care between January 1, 2019, and December 31, 2023, over a five-year period, and who were diagnosed with T2DM or its preclinical state. Data were processed using the Medworks database of the institute, based on outpatient medical records from the specified period. The study was retrospective, cross-sectional, and longitudinal in nature. The examined parameters included:

- The circumstances of carbohydrate metabolism disorder diagnosis, specifically the reason for conducting laboratory tests for diagnostic purposes:
    - Occupational health fitness examination;
    - Presence of symptoms or complaints;
- Examination due to complications;
    - Screening due to risk factors;
- Other reasons (e.g., license renewal, other health problems, or preoperative evaluation);
- Unknown (no indication of diagnostic circumstances in medical documentation).
- The age at which carbohydrate metabolism disorder was diagnosed;
- The type of carbohydrate metabolism disorder:
    - Definitive diabetes;
    - Prediabetes (IFG, IGT, or the simultaneous presence of both).

I categorized the patients into either the "defense sector" or one of the "civilian populations." Within the "defense sector," I created two subgroups.

The "military" subgroup included individuals who were part of the personnel of defense organizations or had retired from such positions.

The "law enforcement" subgroup included individuals who were part of the personnel of law enforcement agencies, those who had retired from such positions, as well as members of the National Assembly Guard and those retired from its personnel.

The "civilian" population included railway personnel, eligible family members, individuals treated under territorial service obligations, and patients who attended our outpatient clinic for other reasons.

I performed the comparison and analysis of data specific to defense sector employees and the civilian population using the JASP (Jeffreys's Amazing Statistics Program) software, employing quantitative exploratory statistical methods. In compliance with data protection laws, I exclusively worked with anonymized data.

Sample Characteristics and Results

I processed data from a total of 4,820 patients. The defense sector group included 2,241 individuals, consisting of 998 military personnel and 1,243 law enforcement personnel, while the

civilian group included 2,579 individuals. The number of individuals in the defense sector and civilian population was nearly similar, 46.50% (n=2,241) vs. 53.50% (n=2,579) (*Table 2*).

Group	Frequency (n)	Percent (%)
Defense sector	**2241**	**46.494**
Military	998	20.706
Law enforcement	1243	25.788
Civilian population	**2579**	**53.506**
Total population	**4820**	**100.000**

Table 2: Composition of the total population by groups and subgroups

Based on gender distribution, there were more men than women, a trend observed not only in the overall study population (57.26%, n=2,760 vs. 42.74%, n=2,060) but also in the main groups and subgroups (military: 64.43%, n=643 vs. 35.57%, n=355; law enforcement: 64.52%, n=802 vs. 35.48%, n=441; civilian: 50.99%, n=1,315 vs. 49.01%, n=1,264).

The age at the time of carbohydrate metabolism disorder diagnosis was known in 4,808 cases, with a mean value of 53.0 years in the total population. Similar results were observed across the groups: 53.2 years in the defense sector group, 53.9 years in the military subgroup, 52.7 years in the law enforcement subgroup, and 52.8 years in the civilian group (*Table 3*).

Group	**Valid** (n)	**Missing** (n)	**Median** (years)	**Mean** (years)	**Standard Deviation**	**Minimum** (years)	**Maximum** (years)
Defense sector	**2234**	**7**	**53.000**	**53.200**	**11.379**	**14.000**	**97.000**
Military	993	5	53.000	53.862	11.626	14.000	97.000

Law enforcement	1 241	2	5 2.000	5 2.670	11. 153	18. 000	89. 000
Civilian population	**2 574**	**5**	**5 3.000**	**5 2.819**	**12. 147**	**13. 000**	**94. 000**
Total population	**4 808**	**1 2**	**5 3.000**	**5 2.996**	**11. 797**	**13. 000**	**97. 000**

Table 3: Descriptive statistics of age at the time of carbohydrate metabolism disorder diagnosis in the total population, main groups, and subgroups

The circumstances surrounding the diagnosis of carbohydrate metabolism disorder were unknown in 11.21% of cases (n=540), meaning that no medical documentation was available to determine the reason behind the abnormal laboratory result. Among the 4,280 cases with known circumstances, the metabolic disorder was most frequently identified through laboratory tests conducted for other reasons: 71.44% in the total population (n=3,058), 70.85% in the defense sector group (n=1,471), of which 71.16% were in the military subgroup (n=659) and 70.60% in the law enforcement subgroup (n=812), and 72.00% in the civilian group (n=1,587). The second most common circumstance leading to diagnosis was laboratory testing related to symptoms or complaints indicative of diabetes, observed in 17.43% of the total population (n=746), 14.69% in the defense sector group (n=305), 15.91% in the law enforcement subgroup (n=183), and 20.00% in the civilian population (n=441). However, in the military subgroup, fitness test results ranked second at 14.03% (n=130). Screening performed due to risk factors was a very rare circumstance for detection, accounting for only 0.56% in the total population (n=24), 0.43% in the defense sector group (n=9),

and similarly in the military subgroup (0.43%, n=4) and the law enforcement subgroup (0.43%, n=5), while it was slightly higher in the civilian group at 0.68% (n=15) (*Table 4).*

Group	**Circumstances of Diagnosis**	**Frequency** (n)	**Percent** (%)	**Valid Percent** (%)	**Cumulative Percent** (%)
Total population	***Fitness Test***	383	7.946	8.948	8.948
	Symptom/Complaint	746	15.477	17.430	26.378
	Complication	69	1.431	1.612	27.990
	Screening	24	0.497	0.561	28.551
	Other Reasons	3058	63.443	71.449	100.000
	Unknown	540	11.211	-	-
	Total	4820	100.000	-	-
Defense sector	**Fitness Test**	266	11.870	12.813	12.813
	Symptom/Complaint	305	13.610	14.692	27.505
	Complication	25	1.116	1.204	28.709

	Screening	9	0.402	0.434	29.143
	Other Reasons	1471	65.640	70.857	100.000
	Unknown	165	7.363	-	-
	Total	2241	100.000	-	-
Military subgroup	**Fitness Test**	130	13.026	14.039	14.039
	Symptom/Complaint	122	12.224	13.175	27.214
	Complication	11	1.102	1.188	29.302
	Screening	4	0.401	0.432	29.734
	Other Reasons	659	66.032	71.166	100.000
	Unknown	72	7.214	-	-
	Total	998	100.000	-	-
	Fitness Test	136	10.941	11.826	11.826

Law enforcement subgroup	**Symptom/Complaint**	183	14.722	15.913	27.739
	Complication	14	1.126	1.217	28.956
	Screening	5	0.402	0.435	29.391
	Other Reasons	812	65.326	70.609	100.000
	Unknown	93	7.482	-	-
	Total	1243	100.000	-	-
Civilian pupulation	**Fitness Test**	117	4.537	5.309	5.309
	Symptom/Complaint	441	17.100	20.009	25.318
	Complication	44	1.706	1.996	27.314
	Screening	15	0.582	0.681	27.995
	Other Reasons	1587	61.535	72.005	100.000
	Unknown	375	14.541	-	-
	Total	2579	100.000	-	-

Table 4: Descriptive statistics of the circumstances surrounding the diagnosis of carbohydrate metabolism disorder

The type of carbohydrate metabolism disorder at the time of diagnosis was known in 4,811 cases, with definitive DM being identified significantly more frequently than prediabetes. In the total population, 93.39% (n=4,493) were diagnosed with DM compared to 6.61% (n=318) with prediabetes. Similarly, in the defense sector group, 91.82% (n=2,054) were diagnosed with DM versus 8.18% (n=183) with prediabetes. Within the military subgroup, the proportions were 90.36% (n=900) vs. 9.63% (n=96), and in the law enforcement subgroup, 92.99% (n=1,154) vs. 7.01% (n=87). In the civilian group, 94.75% (n=2,439) were diagnosed with DM compared to 5.24% (n=135) with prediabetes (*Table 5*).

Group	**Category**	**Count** (n)	**Percent** (%)	**Valid Percent** (%)	**Cumulative Percent** (%)
Total population	**Diabétesz**	4493	93.216	93.390	93.390
	Prediabétesz	318	6.597	6.610	100.000
	Missing	9	0.187	-	-
	Total	4820	100.000	-	-
Defense sector	**Diabétesz**	2054	91.656	91.820	91.820
	Prediabétesz	183	8.165	8.180	100.000
	Missing	4	0.171	-	-
	Total	2241	100.000	-	-

Military subgroup	**Diabétesz**	900	90.180	90.361	90.361
	Prediabétesz	96	9.619	9.639	100.000
	Missing	2	0.200	-	-
	Total	998	100.000	-	-
Law enforcement subgroup	**Diabétesz**	1154	92.840	92.990	92.990
	Prediabétesz	87	6.999	7.010	100.000
	Missing	2	0.161	-	-
	Total	1243	100.000	-	-
Civilian population	**Diabétesz**	2439	94.572	94.755	94.755
	Prediabétesz	135	5.235	5.245	100.000
	Missing	5	0.194	-	-
	Total	2579	100.0	-	-

Table 5: Descriptive statistics of diabetes and prediabetes diagnoses in the total population, main groups, and subgroups

Hypothesis Testing

Hypothesis 1: Among individuals presenting at a diabetology outpatient clinic due to T2DM or prediabetes, carbohydrate metabolism disorders develop at a later age in defense sector workers compared to the civilian population.

Using an Independent Samples T-Test to compare the data of defense sector workers and civilians, no significant difference was found in the age at which carbohydrate metabolism disorder developed (n=4,808, t=-1.116, degrees of freedom (df)=4,806, p=0.264). According to the Brown-Forsythe test, the variances of the two groups were not equal ($p<0.05$), so a Welch's t-test was also applied, yielding similar results: t=-1.121, p=0.262 (*Table 6*).

Independent Samples T-Test	**Statistic**	**df**	**p**
Student	-1.116	4806.000	0.264
Welch	-1.121	4778.124	0.262

Test of Equality of Variances (Brown-Forsythe)	**F**	**df_1**	**df_2**	**p**
	9.317	1	4806	0.002

Group	**N**	**Mean**	**SD**	**SE**	**Coefficient of Variation**
Civilian population	2574	52.819	12.147	0.239	0.230
Defense sector	2234	53.200	11.379	0.241	0.214

Table 6: Results of t-tests applied to test the first hypothesis and descriptive statistics of

age at the time of diagnosis in the defense sector workers and civilian population groups

Hypothesis 2: Among defense sector workers, T2DM or prediabetes is more frequently identified during fitness examinations and less frequently related to symptoms or diabetes complications compared to the civilian population.

According to the Chi-square test, carbohydrate metabolism disorders were significantly more often identified during fitness examinations and significantly less often related to symptoms among defense sector workers compared to the civilian population (χ^2=90.144, df=4, p<0.001, Cramer's V=0.145) (*Table 7*).

Group		Fitness Test	Symptom/ Complaint	Complication	Screening	Other reasons	Total
Civilian population	Count	1	44	44.0	1	1	2
		17.000	1.000	00	5.000	587.000	204.000
	Expected Count	1	38	35.5	1	1	2
		97.227	4.155	32	2.359	574.727	204.000
Defense sector	Count	2	30	25.0	9	1	2
		66.000	5.000	00	.000	471.000	076.000
	Expected Count	1	36	33.4	1	1	2
		85.773	1.845	68	1.641	483.273	076.000
Total population	Count	3	74	69.0	2	3	4
		83.000	6.000	00	4.000	058.000	280.000
	Expected Count	3	74	69.0	2	3	4
		83.000	6.000	00	4.000	058.000	280.000

Chi-Squared Tests	Value	df	p

X^2	90.144	4	< .001
N	4280		

Nominal	**Value**
Contingency coefficient	0.144
Phi-coefficient*	NaN
Cramer's V	0.145
Lambda (rows)	0.000
Lambda (columns)	0.072
Lambda (symmetric)	0.036

* *Phi coefficient is only available for 2 by 2 contingency tables.*

Table 7: Statistical Analysis for Testing the Second Hypothesis

Discussion

Compared to the civilian population, defense sector workers likely engage higher levels of physical activity, as maintaining physical fitness is not only a personal choice but also a professional requirement enforced through regular fitness examinations. This may encourage them to place greater emphasis on a healthy lifestyle, and factors related to this could have a favorable impact on metabolic balance and help reduce the risk of disease. Based on this, I hypothesized in the first hypothesis that carbohydrate metabolism disorders would develop, and thus be diagnosed, at a later age in defense sector workers.

There is a slight difference in the average age at diagnosis between the defense sector and civilian population groups; however, according to the statistical test, this difference is not significant ($p > 0.05$). Therefore, the first hypothesis was not confirmed.

The results suggest that the lifestyle of defense sector workers does not differ significantly from that of the civilian population, as hypothesized. However, other lifestyle factors characteristic of military and law enforcement personnel, such as sleep quantity and quality or stress,

may counteract the presumed beneficial effects of increased physical activity. T2DM has been associated with shorter sleep duration and poor sleep quality. One study found that the relative risk of carbohydrate metabolism disorders increased by approximately 9% for every hour of reduced sleep duration. [21] This risk factor is prevalent among military and law enforcement personnel, as their work inherently involves night shifts or rotating shifts, which disrupt the body's physiological biorhythms. It has long been known that the metabolic reactions triggered by increased stress in the body can contribute to the onset or progression of T2DM symptoms. Employees in defense organizations often work under unconventional conditions, facing heightened physical and psychological stress. Their duties may endanger their own physical safety, and they frequently confront the consequences of harm to human life, physical integrity, or material assets. Additional factors can also serve as sources of stress. For instance, one of the key characteristics of these organizations—the hierarchical structure—can itself be a source of tension, even in times of peace.

According to current regulations, defense sector workers are subject to more frequent (and stricter) medical examinations, which may lead to earlier detection of carbohydrate metabolism disorders before they progress to a more severe stage, causing symptoms, complaints, or complications. Laboratory tests performed during routine examinations contribute to the possibility of diagnosing the disorder at a younger age, making it more challenging to detect age differences between the two main groups.

In the case where the civilian group is compared separately with the military and law enforcement subgroups regarding age at diagnosis, a statistically significant difference is found at the 95% level based on variance analysis (df = 2, F-test (F) = 3.444, p = 0.021). According to the results of the Post Hoc test, the metabolic disorder was diagnosed significantly earlier in the law enforcement group compared to the military group (mean difference: -1.192 years, standard error: 0.502, t = -2.375, pTukey = 0.046). The mean age at diagnosis in the law enforcement group was 52.670 years (SD = 11.153), whereas it was 53.862 years (SD = 11.626) in the military group. Additionally, in the civilian population, the metabolic disorder was also diagnosed at a significantly earlier age compared to the military group (mean difference: -1.043 years, pTukey = 0.047, t = -2.368) (*Table 8*).

Group	**Sum of Squares**	**df**	**Mean Square**	**F**	**p**	**η^2_p**
Civilian population/	957.639	2				

Military subgroup/ Law enforcement subgroup			478.819	3.444	0.031	0.001
Residuals	667996.278	4805	139.021	-		

Group	**N**	**Mean**	**SD**	**SE**	**Coefficient of Variation**
Civilian population	2574	52.819	12.147	0.239	0.230
Military subgroup	993	53.862	11.626	0.369	0.216
Law enforcement subgroup	1241	52.670	11.153	0.317	0.212

Group		**Mean Difference**	**SE**	**t**	**Ptukey**
	Civilian population	-0.149	0.407	-0.366	0.929

Law enforcement subgroup	**Military subgroup**	-1.192	0.502	-2.375	0.046
Civilian population	**Military subgroup**	-1.043	0.440	-2.368	0.047

Table 8: Comparative Statistics of Age at the Onset of Carbohydrate Metabolism Disorder among the Civilian Population Group, Military Subgroup, and Law Enforcement Subgroup

This result could imply that the risk of developing carbohydrate metabolism disorders is higher among law enforcement personnel, or that these disorders are detected at an earlier age in this group. However, this conclusion should be approached with caution, as the differing standard deviations and non-homogeneous variances suggest that the internal composition of the two groups may differ. Within the defense sector, various occupational categories (e.g., soldiers, police officers, firefighters) may have different risk profiles that influence the age at which metabolic disorders develop. The civilian population, being much more heterogeneous, could also affect the outcomes.

Considering the data for the entire study population, T2DM was diagnosed earlier among men, particularly in the 40-64 age group, with the highest incidence between ages 50-54. For women, the peak in diagnoses occurred at a later age, between 55-59 years. When both sexes are considered, the situation is most critical in the 45-64 age group, as this is where the highest number of diagnoses were recorded (*Figure 1*).

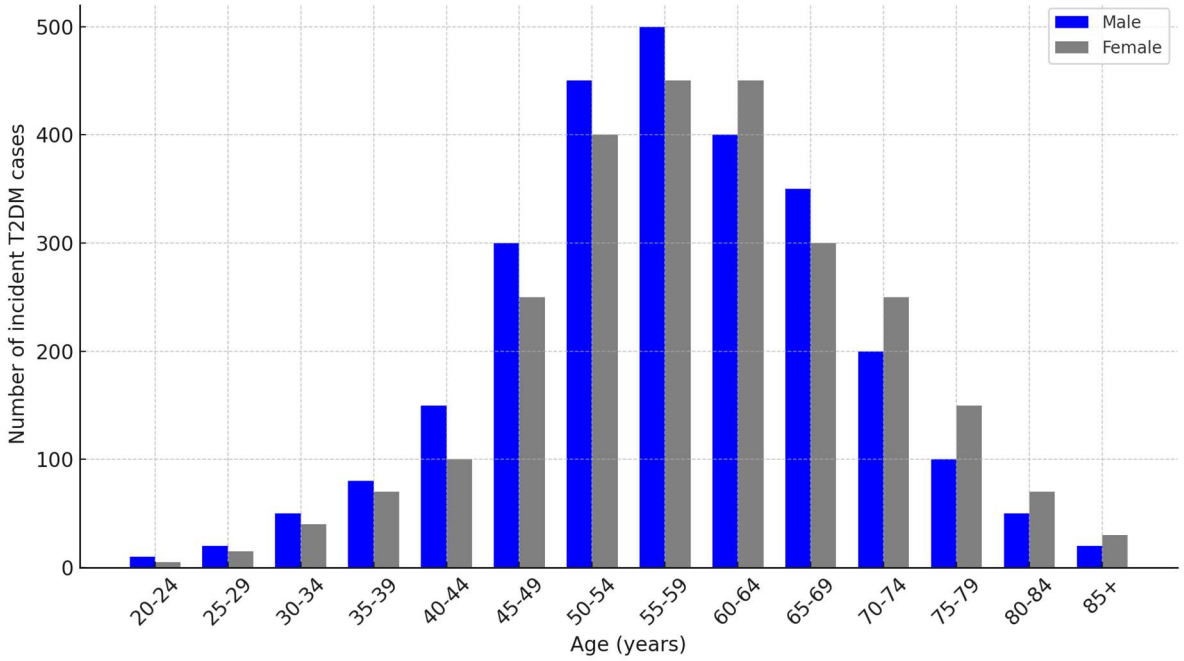

Figure 1: Gender Distribution of T2DM Cases Across Five-Year Age Groups

Based on a previous analysis of the NEAK database, regarding newly registered T2DM cases in 2016, a male predominance was observed in the 35–64 age range, while a female predominance was noted below 35 and above 65 years of age. [2] Direct comparison between the two datasets is not possible due to methodological differences, as the data in my study include retrospective records of individuals diagnosed with diabetes between 1961 and 2023. Nonetheless, the patterns observed in the distribution of age and gender show similarities.

With increasing age, the number of new T2DM cases rises in both genders; however, gender differences play a crucial role in the timing of diagnosis, as the defense sector demonstrates a male predominance. Although the proportion of women in the Hungarian Defense Forces has been steadily increasing over the past decades—rising from approximately 1% in earlier years to 15-16% in the second half of the 2000s and reaching about 20% of the total personnel by 2018- the sector remains male-dominated. [22] [23]

The statistical analysis supports the second hypothesis, which posited that carbohydrate metabolism disorders are more likely to be identified during fitness examinations among defense sector workers compared to the civilian population. The proportion of diagnoses made during fitness examinations was the lowest in the civilian population (5.31%, n=117), suggesting that early detection was less effective in this group, and diagnoses often occurred at a later stage of the disease.

The diagnosis of carbohydrate metabolism disorders due to symptoms or complaints was the second most common reason for detection in most groups. Although relatively low, a non-negligible proportion of cases (1.61%, n=69) were identified in connection with chronic complications, suggesting that for some patients, the condition was only detected at a more advanced stage, possibly after a longer duration of the disease. Targeted screening performed due to existing risk factors was extremely rare (0.56%, n=24) in the study population, even though such screenings, alongside positively influencing risk factors, have the greatest preventive potential.

In terms of the type of diagnosed carbohydrate metabolism disorder, the proportion of prediabetes cases was slightly higher in the defense sector group compared to the civilian population (8.18%, n=183 vs. 5.24%, n=135). However, it should be noted that the diagnoses were made over a broad time period, spanning from 1961 to 2023 (Figure 2).

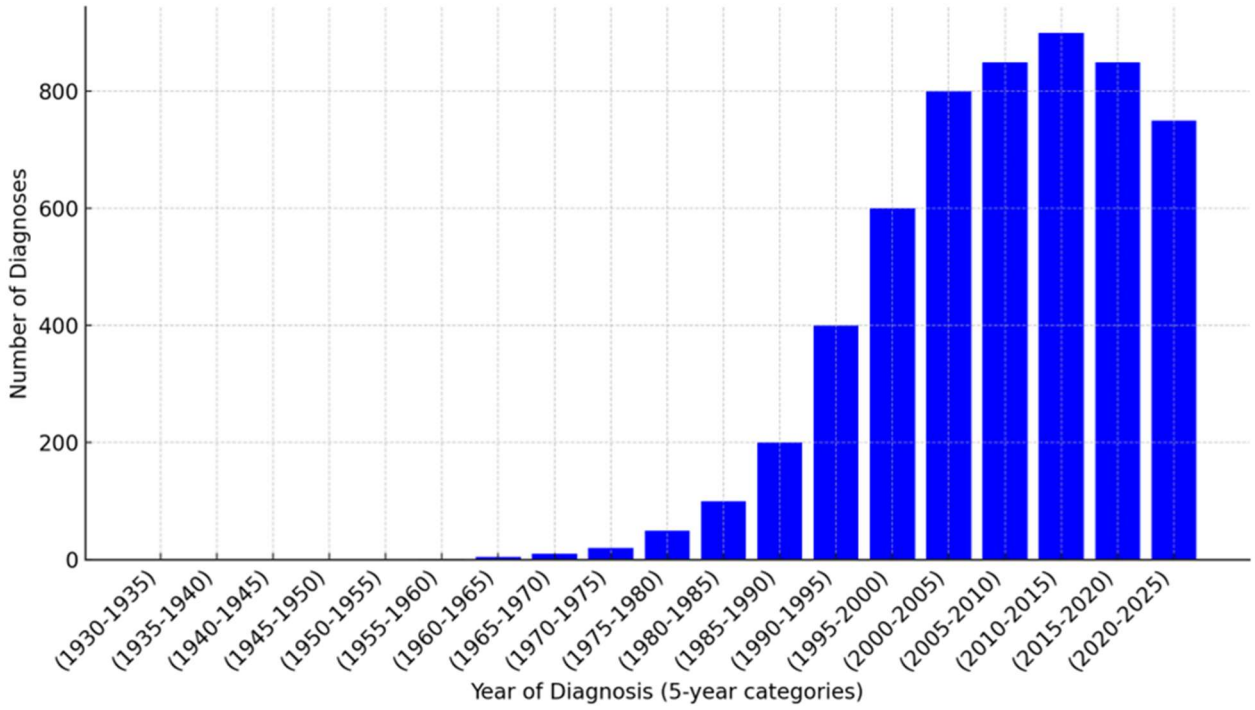

Figure 2: Number of Diagnoses of Carbohydrate Metabolism Disorders Over Five-Year Intervals

During this period, significant changes occurred in the development of diagnostic tools, the applied diagnostic criteria, and the definition and categorization of prediabetes. In previous decades, diagnostic methods were limited, and the identification of prediabetes as a distinct category was not always feasible.

The diagnosis of DM followed the recommendations adopted by the WHO in 1980 [24], which were revised in 1985. [25] The diagnosis was based on "hyperglycemia and associated glycosuria"[4], „most often determined through urine testing". [26] [27] As early as the 1980s, impaired glucose tolerance was distinguished from definitive DM, and by the second half of the decade, glycosuria was removed from the diagnostic criteria. In 1997, the ADA proposed a new classification system along with a diagnostic criteria system, recommending modified thresholds and the differentiation of the IFG condition. [28] For many years, diagnosis relied on venous blood glucose values, as the ADA first included HbA1c in its recommendations in 2010. Initially, HbA1c values between 5.7% and 6.4% were considered indicative of an increased risk of DM, but in the 2016 recommendations, this range was explicitly referred to as prediabetes. [29] [30]

Despite advancements in diagnostic procedures and changes in international guidelines over the past decades, which have made the detection and documentation of carbohydrate metabolism disorders significantly more accurate, and despite the availability of professional recommendations for T2DM screening, the identification of prediabetic conditions remains ineffective. This is supported by a retrospective study conducted among active-duty members of the U.S. military, which found that between 2014 and 2018, risk-based screening would have been justified for approximately 47.3–56.0% of the total personnel, but it was only performed in 4.8–6.7% of cases. Among those who underwent laboratory blood tests, the results met the criteria for prediabetes in one out of every four individuals, yet according to health records, fewer than half of these individuals received an actual diagnosis. [31]

Conclusions

The results highlight the need to strengthen and improve the methods of screening systems, one of the most important tools of prevention, including health fitness examinations. Early detection and effective treatment of carbohydrate metabolism disorders, along with the prevention of complications, are key to maintaining workability, ensuring the individual remains in their career, and sustaining the operational readiness of defense forces.

The main limitation of the study is its cross-sectional nature, as the data spans a five-year period, which did not allow for the examination of causal relationships. Future research should aim

[4] The term glycosuria, as opposed to glucosuria, refers tot he presence of not only glucose but also other types of sugars (e.g. fructose, galactose) in the urine

to collect more detailed information on the circumstances of individual diagnoses, with a particular focus on the process and effectiveness of screenings. It would also be beneficial to consider differences between occupational categories within defense organizations regarding working conditions, lifestyle, physical activity, demographics, psychosocial status, and health fitness and screening practices. Conducting longer-term longitudinal studies would be valuable to enable temporal tracking of disease development.

Potential confounding factors may have influenced data collection, such as variations in access to healthcare services across different groups and changes in the diagnostic methods of carbohydrate metabolism disorders over time.

Additionally, expanding individuals' knowledge is crucial to ensure that diabetes is not diagnosed only after prolonged symptoms, complaints, or the appearance of complications. If it is confirmed that an individual has a high risk of developing diabetes or is already in a prediabetic state, every effort should be made to empower them to take an active role in managing their health to more effectively prevent disease progression.

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THE PREVALENCE OF CHRONIC MACROVASCULAR COMPLICATIONS AMONG DIABETIC PATIENTS: A COMPARATIVE ANALYSIS BETWEEN DEFENSE SECTOR EMPLOYEES AND THE CIVILIAN POPULATION BASED ON HELATH DATA OF PATIENTS TREATED AT THE NORTH-PEST CENTRAL HOSPITAL-MILITARY HOSPITAL

Abstract

Background: Chronic macrovascular complications significantly impact the prognosis of individuals with type 2 diabetes mellitus (T2DM). These complications contribute to reduced quality of life, work limitations, disability, and premature mortality. Epidemiological studies indicate that cardiovascular diseases (CVDs) are among the leading causes of death in diabetic patients. Despite extensive research, the increased mortality risk associated with diabetes cannot be fully explained by traditional cardiovascular risk factors alone.

Objective: This study aims to compare the prevalence and onset of chronic macrovascular complications between employees of the defense sector and the civilian population receiving care at the North Pest Centrum Hospital-Honvéd Hospital (ÉPC-HK) Diabetology Outpatient Clinic between 2019 and 2023.

Methods: A retrospective, cross-sectional, and longitudinal analysis was conducted using anonymized medical data from 4,820 patients diagnosed with T2DM or prediabetes. The study compared the prevalence and timing of macrovascular complications between defense sector employees (n=2,241) and civilians (n=2,579). Statistical analyses were performed to evaluate differences in disease duration before complication onset.

Results: The findings indicate that defense sector employees had a significantly lower prevalence of chronic macrovascular complications compared to civilians ($p<0.001$). Additionally, complications developed later in the defense sector group than in civilians ($p=0.037$). The most

common initial macrovascular complication was carotid artery stenosis (34.02%), followed by coronary artery disease (24.17%), myocardial infarction (17.89%), and stroke (16.06%).

Conclusion: The results suggest that the stricter health standards and regular medical screenings required for defense personnel may contribute to a lower prevalence and delayed onset of diabetic macrovascular complications. Further longitudinal research is needed to determine the extent to which occupational health policies and lifestyle factors influence these outcomes in both defense and civilian populations.

Keywords: TYPE-2 DIABETES MELLITUS, CARDIOVASCULAR DISEASE, MEDICAL FITNESS, HEALTH OF DEFENSE SECTOR, DIABETES DURATION

Introduction

According to 2019 data from the World Health Organization (*WHO*), 74% of deaths worldwide and 94% of deaths in Hungary were caused by chronic diseases, including cardiovascular diseases, malignant tumors, diabetes, and respiratory disorders. As a result, the probability of premature mortality[5]—death occurring before the expected lifespan—was 22% in Hungary. [1] According to information published by the International Diabetes Federation (IDF)[6], the prevalence[7] of diabetes mellitus (*DM*) is increasing worldwide at such a rate that it has become one of the fastest-growing health challenges of the 21st century. Among individuals aged 20–79 years, the number of people affected by diabetes is projected to reach 783 million by 2045. [2]

Diabetes is a carbohydrate metabolism disorder that affects the entire body, caused by a deficiency or reduced effectiveness of insulin, a hormone produced by the beta cells of the pancreas. Type 2 diabetes mellitus (*T2DM*) is the most common form, accounting for approximately 90% of cases, where the disorder results from a relative insulin deficiency or decreased insulin effectiveness. Its development is influenced by genetic and environmental factors, as well as their consequences. Among these, a sedentary lifestyle, obesity, and stress are key contributors. Due to these factors, this disease is often referred to as a disease of civilization. Treatment primarily focuses on lifestyle modification, including a healthy diet, increased physical activity, sufficient and high-quality sleep,

[5] Premature mortality refers to death occurring before the average expected lifespan, often due to preventable causes such as chronic diseases, accidents, or lifestyle-related factors.

[6] The IDF is an international organization whose mission is to combat diabetes and coordinate efforts against it on a global scale

[7] The proportion (prevalence) of individuals suffering from a specific disease within the total population

mental health restoration… These measures are often supplemented with blood glucose-lowering medications, for which there is an extensive range of options available.

The disease primarily determines the patient's fate through the development of complications: it reduces quality of life, leads to limited work capacity and disability, and ultimately shortens life expectancy. The potentially life-threatening short-term (acute) complications of diabetes are related to sudden changes in blood glucose levels. In contrast, long-term (chronic) complications primarily involve vascular damage, which, over time, can result in irreversible organ dysfunction. Microvascular damage most commonly affects the optic nerve or retina, the smallest blood vessels of the kidneys, or the nervous system.

Diabetes-related accelerated atherosclerosis[8] is among the macrovascular complications leading to cardiovascular diseases (*CVD, Cardiovascular Disease; ASCVD, Atherosclerotic Cardiovascular Disease*), which involve the narrowing or occlusion of cardiac, cerebral, and peripheral arteries. According to IDF estimates, in 2021, more than 6.7 million deaths worldwide among individuals aged 20–79 years were attributed to diabetes-related causes. More than 60% of these were linked to CVD conditions, which frequently develop as complications of diabetes but can also occur independently. [2] Data from the Hungarian Central Statistical Office (*KSH, Központi Statisztikai Hivatal*), indicate that CVDs are among the leading causes of death in Hungary. [3] A multinational study published in 2021, including data from more than 9,800 patients with T2DM across 13 countries spanning five continents, found the prevalence of CVD to be 34.8%, with 85.8% of cases associated with diabetes-related accelerated atherosclerosis. [4] Chronic complications can already be present in the prediabetes stage, when blood glucose levels have not yet reached the diagnostic threshold but remain above normal. [5] [6]

As end-stage complications, blindness, kidney transplantation or dialysis-requiring renal failure, myocardial infarction, stroke, and limb damage requiring amputation may develop, leading to premature mortality. The latter increased by 5% due to diabetes between 2000 and 2016. [7] Previous studies have shown that the risk of CVD-related mortality doubles in the presence of T2DM. [8] [9] The increased mortality risk in diabetes cannot be fully explained by traditional cardiovascular

[8] Atherosclerosis is a condition in which deposits, known as plaques, form inside the arteries. These plaques consist of platelets, cholesterol, calcium, and other substances. Over time, they lead to arterial stiffness and narrowing, ultimately impairing blood flow.

risk factors,[9] genetic background, insulin resistance,[10] and the occurrence of critically low blood glucose levels (hypoglycemia) during treatment also play a role. [10] In light of this, the duration of carbohydrate metabolism disturbances may show significant individual differences in the development of CVD.

In line with the clinical burden of CVD, increasing attention has been given over the past decade to the integrated management of these conditions and T2DM within a holistic approach. Epidemiological data and clinical studies alike support the significant overlap between cardiovascular, renal (kidney), and metabolic diseases in terms of shared risk factors and common pathogenesis. Recognizing these complex interrelations, the American Heart Association (*AHA*) recently introduced the concept of Cardiovascular-Kidney-Metabolic Syndrome (*CKM*), highlighting the close associations and interactions between CVD conditions, chronic kidney disease, and T2DM. [11]

In Hungary, a confirmed diagnosis of any form of diabetes is considered a disqualifying condition for applicants to military and law enforcement educational institutions. The medical fitness of personnel serving in the Hungarian Defence Forces is determined and assessed by an occupational physician, an occupational health specialist, or a specialist with professional experience in medical fitness examinations and aeromedical assessments. The requirements for the relevant professional practice are established by appropriate regulations and directives. [12] [13] [14] If diabetes is diagnosed or any of its complications are detected during the validity period of the "Fit for Service" qualification, which render the individual unfit for military service or their assigned duty position, a medical review process must be initiated. For personnel already in service, medical fitness in the presence of diabetes primarily depends on the method of treatment, metabolic stability, and the presence of complications. From an occupational perspective, uncontrolled diabetes and long-term complications (such as advanced renal failure, heart failure, or stroke with residual symptoms) constitute grounds for unfitness. For law enforcement personnel, the medical fitness criteria for individuals with diabetes are defined by regulations and directives governing the medical fitness assessments of professional and administrative staff employed by law enforcement agencies. [15] [16] In certain directives, for specific officer and non-commissioned officer classification categories,

[9] The traditional risk factors for cardiovascular diseases, besides diabetes, include obesity, physical inactivity, older age, male sex, family history, smoking, excessive alcohol consumption, hypertension, abnormal blood lipid levels, and chronic stress.

[10] Insulin resistance is a condition in which the body's cells respond less effectively to the hormone insulin, despite the pancreas producing a sufficient (or even excessive) amount of it.

insulin-treated diabetes constitutes grounds for disqualification. However, personnel with complication-free, medication-managed diabetes may be deemed fit for service only if they have not experienced severe hypoglycemia in the 12 months preceding the examination and are fully aware of its early symptoms and associated risks. Regular occupational health assessments, which include the identification and management of risk factors, as well as compliance with physical fitness requirements, suggest that individuals with carbohydrate metabolism disorders may develop CVDs at an older age and in lower numbers.

One of the key determinants of the work capacity of individuals living with diabetes is the primary tool of treatment itself—achieving and maintaining proper glycemic control, meaning that blood glucose levels remain within the appropriate (therapeutic) range.

In recent decades, innovative therapeutic agents have become available that offer benefits beyond ensuring long-term metabolic stability. These agents reduce the incidence of CVD-related complications, slow their progression, and ultimately improve survival rates. Based on these effects, medications within these drug classes can justifiably be referred to as Disease/Diabetes Modifying Drugs (*DMDs*)[11], whose introduction into therapy is strongly recommended.

The North Pest Central Hospital – Military Hospital (*ÉPC-HK, Észak- Pesti Centrumkórház-Honvédkórház*) and its predecessor, the Hungarian Defence Forces Medical Center (*MHEK, Magyar Honvédség Egészségügyi Központ*), were established on July 1, 2007, under the name State Health Center, through the merger of several institutions, including the Military Hospital (*Honvédkórház*), the Central Hospital of the Ministry of the Interior (Belügyminisztérium Központi Kórháza), the National Institute of Medical Care (Országos Gyógyintézeti Központ) and the Hungarian State Railways Hospital (Magyar Államvasutak Kórháza). [17] The institution's primary mission became military healthcare support, but with the integration, the civilian population—primarily in the North Pest region—progressively became a focus of care. Over the years, several structural transformations have taken place; however, the eligibility for care has remained unchanged. As a result, the hospital continues to provide healthcare services not only to residents of certain districts in Budapest but also to personnel of defense agencies, including diabetological care.

[11] Such medications include sodium-glucose co-transporter-2 inhibitors (SGLT2i) and glucagon-like peptide-1 receptor agonists (GLP1RA), which have rightfully earned their place not only in diabetology but also in professional guidelines for cardiovascular disease, nephrology, and obesity management.

Objective

The aim of this study is to examine the circumstances of carbohydrate metabolism disorder diagnosis and the prevalence of chronic macrovascular complications that most significantly determine medical fitness among patients with T2DM or prediabetes who were under care at the Diabetology Outpatient Clinic of the ÉPC-HK between January 1, 2019, and December 31, 2023. This publication retrospectively analyzes the relationship between these complications and age and disease duration, comparing data from defense personnel and the civilian population. Furthermore, it contrasts the findings with available literature and statistical data.

Hypotheses

1. First Hypothesis: Among patients who attended the diabetology outpatient clinic for T2DM or prediabetes, the prevalence of chronic macrovascular complications is lower in defense personnel compared to the civilian population.

2. Second Hypothesis:Among patients who attended the diabetology outpatient clinic for T2DM or prediabetes, chronic macrovascular complications occur after a longer disease duration in defense personnel compared to the civilian population.

Methodology

This study was conducted with prior research approvals from the Scientific and Research Ethics Committee of the Health Science Council (*TUKEB*) (BM/26853-1/2024) and the Regional Research Ethics Committee (*RKEB*) (EPCHK-RKEB-2024/11/06-2).

The research analyzed the health data of individuals who attended the Diabetology Outpatient Clinic of ÉPC-HK) for diabetology care between January 1, 2019, and December 31, 2023, and were diagnosed with T2DM or its precursor state. Data were extracted from the institution's MedWorks database based on ambulatory records from the specified period.

The study employed a retrospective cross-sectional and longitudinal design. The characteristics of carbohydrate metabolism disorder diagnosis (circumstances of detection, age at

diagnosis) were presented in a previous publication. The additional parameters examined in this study included:

- presence of chronic macrovascular complications of diabetes;
- type of the first diagnosed macrovascular complication, if present:
    - Coronary Artery Disease (*CAD*)[12];
    - myocardial infarction (heart attack)[13];
    - mortality due to myocardial infarction;
    - at least 50% stenosis in at least one major coronary artery, based on invasive contrast-enhanced imaging[14] results or requiring intervention[15], without myocardial infarction;
    - cerebrovascular disease:
        - stroke due to vascular insufficiency;
    - mortality due to stroke caused by vascular insufficiency;
    - At least 50% stenosis or occlusion of the internal carotid artery[16], diagnosed by ultrasound, magnetic resonance imaging (*MRI*), or contrast-enhanced imaging, or its surgical revascularization[17];
    - Lower extremity peripheral Arterial Disease (*PAD*):

[12] The coronary arteries are the blood vessels responsible for the heart's own blood supply, delivering oxygen-rich blood to the myocardium (heart muscle).

[13] A myocardial infarction (MI, heart attack) is the necrosis of a portion of the heart muscle, caused by the occlusion of the coronary arteries and the sudden interruption of blood supply to the myocardium.

[14] Coronary invasive contrast-enhanced imaging is a catheter-based diagnostic procedure** that maps the coronary arteries by injecting contrast material directly into the heart's blood vessels and using X-ray imaging to visualize them.

[15] A coronary artery intervention is a procedure aimed at treating narrowing or occlusion of the coronary arteries, thereby restoring blood flow to the heart muscle. The most common forms are percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG). PCI is a catheter-based procedure that involves balloon angioplasty and often stent implantation to open the blocked artery. CABG is a surgical procedure in which a bypass graft is created using another blood vessel to reroute blood flow around the narrowed or blocked coronary artery segment.

[16] The internal carotid artery is a branch of the carotid artery, responsible for supplying blood to a significant portion of the brain, particularly the anterior and middle cerebral regions.

[17] Revascularization is a medical procedure aimed at restoring blood flow to an occluded or narrowed blood vessel.

- intermittent claudication[18] and an ankle-brachial index (*ABI*)[19] below 0.9;
- non-traumatic amputation or peripheral surgical revascularization due to peripheral artery disease (PAD);
- aortic dissection or aneurysm;

- age at the time of the first diagnosed macrovascular complication;
- disease duration at the time of the first diagnosed macrovascular complication.

I classified ischemic[20], hemorrhagic[21], and undefined strokes as cerebrovascular events due to vascular insufficiency. Among CVDs, I did not consider the presence of transient ischemic attack (*TIA*)[22], non-ischemic heart failure, or cardiac arrhythmias (such as atrial fibrillation, atrial flutter, or ventricular tachycardia). For patients who did not attend follow-up visits during the final six months of the study period (July 1, 2023 – December 31, 2023), I marked the presence of complications as "missing data".

I categorized patients into "defense sector" and "civilian population"groups. Within the defense sector, I created two subgroups: the "military" subgroup included individuals actively serving or retired from defense organizations and the "law enforcement" subgroup included active and retired personnel of law enforcement agencies, members of the Parliamentary Guard, and their retired personnel. The "civilian population" category included railway employees, eligible family members, individuals treated based on regional healthcare obligations and other patients who attended the clinic for various reasons.

I conducted a statistical comparison between the defense sector and civilian populations using JASP (Jeffreys's Amazing Statistics Program), applying quantitative exploratory statistical methods. In compliance with data protection regulations, I exclusively worked with anonymized data.

Sample Description

[18] Intermittent claudication is a characteristic symptom of peripheral vascular disease (PVD), presenting as exercise-induced leg pain that subsides with rest. It is caused by oxygen deficiency in the lower limb muscles, resulting from arterial narrowing or occlusion. The pain typically occurs while walking, forcing the patient to stop for relief.

[19] The ankle-brachial index (ABI) is a diagnostic measurement used to detect peripheral vascular disease (PVD). It represents the ratio of blood pressure in the lower and upper extremities, with a normal range between 0.9 and 1.3. ABI below 0.9 may indicate arterial narrowing (PAD).ABI above 1.3 may suggest arterial wall calcification.

[20] Tissue damage due to inadequate blood supply, usually caused by arterial occlusion.

[21] Bleeding caused by vessel rupture.

[22] A transient neurological condition resulting from temporary disruption of blood flow to specific brain regions, often a precursor to stroke, but without causing permanent damage.

A total of 4,820 patient records were analyzed. Of these, 2,241 individuals belonged to the defense sector group, including 998 military personnel and 1,243 law enforcement personnel. The civilian group consisted of 2,579 individuals. The distribution between the defense sector and civilian population was nearly equal, with 46.50% (n=2,241) in the defense sector and 53.50% (n=2,579) in the civilian group (*Table 1*).

Group	Frequency (n)	Percent (%)
Defense sector	**2241**	**46.494**
Military	998	20.706
Law enforcement	1243	25.788
Civilian population	**2579**	**53.506**
Total population	**4820**	**100.000**

Table 1: The composition of the entire population by groups and subgroups.

In 87.13% (n=4,200) of the examined population, health status data were available, allowing for the assessment of the analyzed complications. Among these individuals, 86.21% (n=3,621) showed no evidence of any of the studied macrovascular complications. In 13.78% (n=579) of cases, at least one major vascular complication was present. Among the first-diagnosed macrovascular complications, the most frequently observed conditions were internal carotid artery stenosis or occlusion (34.02%, n=197), followed by coronary artery stenosis (24.17%, n=140), myocardial infarction (17.78%, n=103), and stroke (16.06%, n=93). Less frequently, the first complication was non-traumatic amputation or peripheral surgical revascularization due to peripheral artery disease (5.87%, n=34), intermittent claudication with a low ankle-brachial index (1.72%, n=10), and in only one case each, mortality due to myocardial infarction (0.17%) and stroke (0.17%). Notably, aortic dissection or aneurysm did not occur as a first-diagnosed complication in the study population (*Table 2*).

Complications	Frequency	Percent	Valid Percent	Cumulative Percent
Myocardial infarction	103	2.137	2.452	2.452
Death due to myocardial infarction	1	0.021	0.024	2.476
Coronary stenosis[1]	140	2.905	3.333	5.809
Stroke	93	1.929	2.214	8.023
Death due to stroke	1	0.021	0.024	8.047
Carotid artery stenosis[2]	197	4.087	4.690	12.737
Intermittent claudication[3]	10	0.207	0.238	12.975
Amputation or revascularization[4]	34	0.705	0.810	13.785
No complication	3621	75.124	86.215	100.000
Missing	620	12.863	-	-

Total	4820	100.00 0	-	-

Table 2: Frequency and Distribution of Complications in the Study Population
1: Coronary stenosis means at least 50% stenosis in at least one major coronary artery based on invasive contrast-enhanced examination results or the need for intervention; 2: Carotid artery stenosis means at least 50% stenosis or occlusion of the internal carotid artery (arteria carotid interna) based on ultrasound examination, magnetic resonance imaging, or contrast-enhanced examination results, or its surgical revascularization; 3: Intermittent claudication with an ankle-brachial index value below 0.9; 4: Non-traumatic amputation or peripheral surgical revascularization procedure due to peripheral artery disease.

At the time of the first diagnosed macrovascular complication, age data were available for 570 individuals. The average age at diagnosis was 66.2 years among those in the defense sector and 62.6 years in the civilian population (*Table 3*).

	Defense sector	**Civilian population**
Valid	226	344
Missing	2015	2235
Median	67.000	64.000
Mean	66.265	62.683
Std. Deviation	10.462	10.574
Minimum	42.000	33.000
Maximum	91.000	88.000

Table 3: Descriptive statistics of age at the occurrence of complications

The lowest average age at the time of the first diagnosed macrovascular complication was associated with myocardial infarction (59.5 years), while the highest average age was linked to internal carotid artery disease (68.1 years). The standard deviation of age varied across different complications, being largest for lower limb amputation or revascularization (12.89) and smallest for intermittent claudication with an abnormal ankle-brachial index (8.11). The minimum age at

diagnosis for all complications ranged between 33 and 50 years, with the youngest cases observed in myocardial infarction (33 years) and coronary artery disease without infarction (33 years) (*Table 4*).

	Valid	Missing	Median	Mean	Standard deviation	Minimum	Maximum
Myocardial infarction	101	2	59.000	59.525	11.874	33.000	86.000
Death due to myocardial infarction	1	0	65.000	65.000	-	-	-
Coronary stenosis[1]	139	1	64.000	63.345	10.182	33.000	87.000
Stroke	92	1	63.000	62.543	9.121	40.000	84.000
Death due to stroke	0	1	-	-	-	-	-
Carotid artery stenosis[2]	194	3	68.000	68.113	9.540	40.000	91.000
Intermittent claudication[3]	9	1	65.000	64.111	8.115	50.000	78.000
Amputation or	34	0	62.000	62.118	12.289	36.000	87.000

revascularization[4]							

Table 4: Descriptive statistics of age at the onset of complications based on the type of complications

1: Coronary stenosis means at least 50% stenosis in at least one major coronary artery based on invasive contrast-enhanced examination results or the need for intervention; 2: Carotid artery stenosis means at least 50% stenosis or occlusion of the internal carotid artery (arteria carotid interna) based on ultrasound examination, magnetic resonance imaging, or contrast-enhanced examination results, or its surgical revascularization; 3: Intermittent claudication with an ankle-brachial index (ABI) value below 0.9; 4: Non-traumatic amputation or peripheral surgical revascularization procedure due to peripheral artery disease.

In 98.27% (n=569) of the 579 cases with macrovascular complications, both the year of carbohydrate metabolism disorder diagnosis and the year of complication onset were known. This allowed for a statistical analysis of disease duration at the time of complication diagnosis. Among 225 cases in the defense sector, the average disease duration was 12.0 years, while in the 344 cases from the civilian population, it was 10.4 years (*Table 5*).

Descriptives	**Group**	**N**	**Mean**	**SD**	**SE**	**Coefficient of variation**
Disease duration until complications, adjusted	**Defense sector**	225	12.067	9.697	0.446	0.804
	Civilian population	344	10.407	8.552	0.461	0.822

Table 5: Descriptive statistics of the average disease duration at the onset of the first major vascular complication in the defense sector and civilian population groups

The complications most frequently appeared 8 to 14 years after diagnosis. The shortest average disease duration was associated with myocardial infarction (8.3 years), while the longest was linked to intermittent claudication (14.0 years). Among the 4,820 individuals examined, the circumstances of carbohydrate metabolism disorder diagnosis were known for 4,280 cases. In 1.61%

(n=69) of cases, T2DM or prediabetes was detected during an evaluation or treatment for complications. This diagnostic circumstance occurred in all analyzed complications except for one case of intermittent claudication related to CVD mortality. Stroke-related mortality was recorded in one case, but the disease duration was unknown. Mortality due to myocardial infarction was also observed in one case, occurring after seven years. It is important to note that the high standard deviation values indicate significant individual variability (Table 6).

	Valid	Missing	Mean	Standard deviation	Minimum	Maximum
Myocardial infarction	101	2	8.337	9.517	0.000	53.000
Death due to myocardial infarction	1	0	7.000	-	7.000	7.000
Coronary stenosis[1]	139	1	11.597	8.400	0.000	40.000
Stroke	92	1	8.957	8.160	0.000	31.000
Death due to stroke	0	1	-	-	-	-
Carotid artery disease[2]	193	4	12.803	8.974	0.000	44.000

Intermittent claudication[3]	9	1	14.000	10.689	1.000	32.000
Amputation or revascularization[4]	34	0	12.147	10.115	0.000	43.000

Table 6: The descriptive statistics of years elapsed from the diagnosis of carbohydrate metabolism disorders to the onset of macrovascular complications

1: Coronary stenosis means at least 50% stenosis in at least one major coronary artery based on invasive contrast-enhanced examination results or the need for intervention; 2: Carotid artery stenosis means at least 50% stenosis or occlusion of the internal carotid artery (arteria carotid interna) based on ultrasound examination, magnetic resonance imaging, or contrast-enhanced examination results, or its surgical revascularization; 3: Intermittent claudication with an ankle-brachial index (ABI) value below 0.9; 4: Non-traumatic amputation or peripheral surgical revascularization procedure due to peripheral artery disease.

Hypothesis Testing

1. First hypothesis: Patients who attended the diabetology outpatient clinic for T2DM or prediabetes had a lower prevalence of chronic macrovascular complications in the defense sector compared to the civilian population.

The chi-square test result (n=4,199, X^2=14.670, df=1, p<0.001, Cramer's V=0.059) indicates that chronic macrovascular complications occur less frequently among defense sector personnel than in the civilian population. However, the Phi coefficient and Cramer's V (0.059) suggest a weak effect size (*Table 7*).

Presence of complications		**Total population**	**Defense Sector**	**Civilian population**
	Count	3621.000	1732.000	1889.000

Without complications	Expected count	3621.000	1689.340	1931.660
With complications	Count	578.000	227.000	351.000
	Expected count	578.000	269.660	308.340
Total	Count	4199.000	1959.000	2240.000
	Expected count	4199.000	1959.000	2240.000

Chi-Squared Tests	**Value**	**df**	**p**
X^2	14.670	1	< 0.001
N	4199		

Nominal	**Value**
Contingency coefficient	0.059
Phi- coefficient	-0.059
Cramer's V	0.059
Lambda (rows)	0.000
Lambda (columns)	0.000
Lambda (symmetric)	0.000

Table 7: Statistical analysis of the first hypothesis testing process

2. Second hypothesis: Among patients who attended the diabetology outpatient clinic for T2DM or prediabetes, chronic macrovasculart complications occur after a longer diasease duration in the defense sector compared tot he civilian pupulation.

The comparison of diesease duration between defense sector personell and civilians using Welch's t-test showed a statistically significant result (n=567, t=-2.090, df=436.151, p=0.037) at the 5% sigfinicance level (*Table 8*).

Independent Sample T-Test	Test	Statistic	df	p
Disease duration until complications, adjusted	Student	-2.146	567.000	0.032
	Welch	-2.090	436.151	0.037

Group	N	Mean	SD	SE	Coefficient of variation
Defense sector	225	12.067	9.697	0.646	0.804
Civilian population	344	10.407	8.552	0.461	0.822

Table 8: Statistical analysis of the second hypothesis testing process, based on the data in Table 5

Discussion

Regarding the first hypothesis, statistical analysis demonstrated a significant difference between the defense sector and the civilian population in the prevalence of macrovascular complications related to diabetes. Based on this, it can be assumed that defense sector personnel are less likely to develop diabetes-related complications. However, the effect size (Cramer's V = 0.059)

is very small, indicating that while the association is statistically significant, it is weak. Despite this, the findings support the notion that the strict physical fitness requirements and more regular health screenings for defense sector personnel may have a protective effect in preventing the development of complications.

The second hypothesis was also confirmed by the statistical analysis, showing a significant difference in disease duration before the onset of complications between defense sector personnel and the civilian population. Diabetes-related complications developed later among individuals working in the defense sector. This finding further supports the benefits of strict physical fitness requirements and regular health screenings in delaying the progression of complications. The coefficients of variation were relatively similar, indicating that the relative variability in disease duration was nearly the same in both groups. The detectability of age-related differences and the shortening of disease duration in the civilian group may also be influenced by the mandatory, more frequent health examinations in the defense sector. These screenings likely lead to an earlier diagnosis of carbohydrate metabolism disorders and, consequently, earlier and more effective treatment. This further supports the validity of the hypothesis.

A study analyzing the results of 57 investigations, covering data from more than 4.5 million individuals with T2DM, found that CVD conditions were present in 32.2% of diabetic patients worldwide, with coronary artery disease and stroke being the most common types. [18] In the population examined in this study, coronary artery disease also ranked first (42.14%, n=244), while stroke was the third most common complication (16.06%, n=93). The results of this analysis were influenced by the inclusion of internal carotid artery stenosis as a complication even at a 50% narrowing threshold. Additionally, TIA events, heart failure without coronary artery disease, and cardiac arrhythmias were not considered in the study.

Conclusion

The results of this study support the finding that chronic macrovascular complications occur less frequently and develop after a longer disease duration in individuals with diabetes who work in the defense sector compared to the civilian population. Although the statistical association in the first hypothesis is weak, the findings suggest that the strict medical protocols and fitness requirements associated with a career in the military and law enforcement may have a preventive effect on the development of diabetes-related complications.

Further longitudinal studies are necessary to understand how much of the health advantage observed in the defense sector can be attributed to occupational requirements, regular medical check-ups, and various lifestyle and health factors influencing the development of diabetes complications in both defense personnel and the civilian population.

The sample adequately represents age-related characteristics across different complications. However, in some categories—such as intermittent claudication and mortality due to myocardial infarction—the low number of cases may limit the validity of statistical analyses.

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Generational Differences and Artificial Intelligence in Hungarian Agricultural Networks: Opportunities and Challenges for Sustainable Agri-Innovation

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Keywords: artificial intelligence, agricultural networks, digital transition, generational differences, sustainable agriculture, decision support, innovation

Abstract

The structural and technological evolution of Hungarian agriculture presents both challenges and opportunities for stakeholders, particularly in terms of network cooperation among farmers. This paper investigates the role of artificial intelligence (AI) in enhancing agricultural networks, with a specific focus on addressing generational differences and promoting sustainability. Younger farmers, who are more inclined to adopt new technologies, contrast with older generations who prefer traditional forms of cooperation. AI, through tools like machine learning and virtual mentoring systems, can bridge this gap by providing personalized support, facilitating digital integration, and improving decision-making processes. Additionally, AI contributes to sustainable practices by optimizing resource usage and supporting climate adaptation strategies. The study highlights the potential of AI not only as a technological tool but as a facilitator of intergenerational collaboration and knowledge transfer, which is crucial for ensuring the resilience of Hungarian agriculture. By integrating traditional knowledge with digital innovation, AI can help cultivate a more sustainable and competitive agricultural sector.

Introduction

Over the past decade, Hungarian agriculture has experienced significant structural and technological transformations. These changes have been driven by a combination of factors, including policy reforms, global market integration, technological advancements, and increasing environmental pressures (Baranyai et al., 2021). These developments have redefined how agricultural production is

organized and managed, presenting both challenges and opportunities for farmers, policymakers, and other stakeholders in the agri-food sector. The growing complexity of agricultural systems necessitates not only technological adaptation but also new forms of cooperation, particularly within knowledge-based networks that facilitate innovation and shared learning (Cristóvão et al., 2012).

One of the most critical developments in this evolving landscape is the emergence and strengthening of agricultural networks. These networks—comprised of farmers, advisors, researchers, suppliers, and institutions—play a vital role in the dissemination of knowledge, the allocation of resources, and the implementation of innovative practices (Ingram et al., 2018). They act as platforms for collective problem-solving, learning, and co-creation, essential for navigating the uncertainties and demands of modern agriculture. However, these networks are not uniform; their organization is influenced by various socio-economic and cultural factors, such as educational background, regional characteristics, and personal attitudes towards innovation (Szűcs, 2022). As such, agricultural networks in Hungary operate as complex, multi-actor systems that require flexible and adaptive coordination mechanisms.

A key social dimension shaping these networks is the generational composition of the farming community. Younger farmers are typically more receptive to digital tools, value fast communication channels, and are more inclined to engage in novel forms of cooperation through online platforms and precision technologies (Koutsouris, 2012; Liakos et al., 2018). In contrast, older generations often adhere to more traditional practices, favor long-term personal relationships, and may be more cautious in adopting digital solutions (Tisenkopfs et al., 2015). This generational divergence in technological orientation and collaboration style can lead to communication barriers and hinder the overall efficiency and inclusiveness of agricultural networks.

In this context, artificial intelligence (AI) emerges as a promising enabler for enhancing network efficiency and cohesion. AI technologies, particularly machine learning and decision-support systems, can facilitate better knowledge flow, optimize resource allocation, and support real-time decision-making in farming operations (Kamilaris et al., 2017; Wolfert et al., 2017). Importantly, AI also has the potential to bridge the digital divide between generations. Virtual advisory systems, personalized information services, and predictive analytics can be tailored to the diverse needs and capabilities of both young and senior farmers, thereby supporting inclusive innovation and intergenerational learning (Rose et al., 2021; Ferronato et al., 2020).

Furthermore, the integration of AI into agricultural practices aligns with broader sustainability goals. As climate change and environmental degradation threaten the viability of traditional farming

methods, AI-enabled precision agriculture can help optimize input use, reduce waste, and enhance the resilience of agricultural systems (Liakos et al., 2018; van Dijk et al., 2020). In this light, AI is not only a technological advancement but a potential catalyst for a paradigm shift toward more sustainable, knowledge-intensive farming systems.

This study aims to investigate the role of artificial intelligence in enhancing the organization and performance of Hungarian agricultural networks. Particular attention is paid to how AI can facilitate collaboration across generations and contribute to sustainability-oriented innovation. By drawing on current literature and practical examples, this research seeks to demonstrate how AI can support both the technological advancement and social inclusivity of Hungarian agriculture in the digital age.

Generational Differences in Agricultural Networks

Younger and older farmers engage differently within agricultural networks. Younger generations exhibit greater technological affinity, openness, and willingness to innovate, contrasting with the older generations' more conservative, traditional relational patterns (Ingram et al., 2018). Young farmers are typically more active on digital platforms, readily adopt precision agriculture tools, and are more open to new forms of network cooperation (Koutsouris, 2012). Conversely, older farmers often prefer stable, long-term partnerships and favor face-to-face communication (Tisenkopfs et al., 2015).

AI-Based Support for Intergenerational Collaboration

Artificial intelligence can open new horizons in organizing and operating agricultural networks. Machine learning algorithms can identify patterns leading to more effective cooperation structures (Kamilaris et al., 2017). AI offers personalized information services, automated partner matching, and predictive decision-making support, significantly contributing to the digital integration of older generations (Wolfert et al., 2017).

Virtual mentoring systems, such as AI-based advisors and chatbots, can serve as intermediaries between generations with differing digital competencies, facilitating shared learning and experience exchange (Rose et al., 2021). Through predictive analytics, AI can forecast the success

of network collaborations by identifying potentially outstanding nodes within the network (Ferronato et al., 2020).

Sustainability and AI in Agriculture

Making agriculture more sustainable is a key strategic goal amid climate change and shrinking resource availability. AI-based systems can support more efficient use of resources—especially water, soil, and nutrients (Liakos et al., 2018). The potential of precision agriculture, such as sensor data analysis and drone technology, can be fully realized only if network participants can integrate these into their operations.

Climate Change and New Crop Cultures

Due to global climate change, it is increasingly urgent in Hungary to disseminate drought-resistant crops and adapt Mediterranean plant species (Baranyai et al., 2021). AI can model climate scenarios that optimize plant adaptation and irrigation strategies (van Dijk et al., 2020). In this way, AI not only increases the resilience of agricultural production but also contributes to maintaining market competitiveness.

Knowledge Transfer and Joint Innovation

Young farmers play a key role in digitally supporting older generations. Joint training sessions, digital tool usage workshops, and innovation workshops offer opportunities for knowledge transfer, which can strengthen the resilience of rural communities in the long term (Cristóvão et al., 2012). In this context, AI is not only a technological tool but also a catalyst in community learning processes.

Conclusions

The integration of artificial intelligence (AI) into Hungarian agricultural networks holds significant potential to enhance overall production efficiency by optimizing resource management, improving crop yields, and reducing operational costs. AI technologies, such as machine learning algorithms, data analytics, and predictive modeling, can provide farmers with valuable insights that

help streamline farming practices, monitor crop health in real-time, and optimize irrigation and nutrient management. These advancements contribute not only to increased productivity but also to the effective use of scarce resources, making agriculture more resource-efficient and environmentally sustainable.

Moreover, AI has the capability to bridge the generational gap that exists within the agricultural community. Younger farmers, who tend to be more familiar with digital technologies, can help older generations integrate AI-powered tools into their operations, fostering intergenerational knowledge transfer and collaboration. AI-driven platforms can offer personalized support, such as virtual mentoring or decision-making assistance, enabling older farmers to adapt to new technologies and practices without feeling overwhelmed by the digital transition. This mutual reinforcement of traditional agricultural knowledge and cutting-edge technological innovation allows for a more holistic approach to farming, where both old and new methods can coexist and complement each other.

Furthermore, the combination of AI and generational collaboration can foster the development of a more sustainable agricultural sector. By using AI to predict and mitigate environmental risks, such as those associated with climate change, farmers can make better-informed decisions about crop selection, irrigation strategies, and pest control. These improvements lead to a more resilient agricultural system that is capable of responding to both current challenges and future uncertainties. The synergy between AI and generational differences can drive the creation of a competitive, adaptive, and innovative agricultural sector, positioning Hungary’s farming community to thrive in the face of global challenges.

Ultimately, the adoption of AI in Hungarian agricultural networks can create a more connected, dynamic, and sustainable farming ecosystem, where technological innovation and traditional knowledge coexist to ensure the sector's long-term viability and success.

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Similarities and Differences Between the Hungarian National Teams of Marco Rossi and Bernd Storck from a Tactical Perspective

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Introduction

The Hungarian national football team has experienced remarkable years. The "Golden Team" was on top of the world, remaining unbeaten for 30 matches between 1950 and 1954. However, something changed thereafter. For 30 long years, our nation failed to qualify for any major international tournament until 2016, when we finally made it to the EURO. We then qualified again for the next continental competition.

Two EURO appearances, two different head coaches, and two eras. In my research, I sought to uncover the main tactical similarities and differences between these periods. I believe the performance of the Hungarian national team has always been a central topic in Hungary, and I have been particularly interested in the football philosophy and tactics of each coach, which can explain the outcomes of certain matches. Thus, I set out to analyze the two most successful national team coaches of recent years, the German Bernd Storck and the Italian Marco Rossi, to better understand the reasons behind successes and failures and gain useful insights for the future.

Literature Review

For my research, I used Jonathan Wilson's Inverting the Pyramid (2014) and Christophe Szabó, Péter Szabó, and Márk Soós's Olvasd a játékot! (2022) as foundational references. Additionally, I consulted match analyses and tactical articles from various sources: from the Bernd Storck era, I relied on the American Bleacher Report (B/R), the British The Guardian, and the Hungarian outlets Telex and Index. For the Marco Rossi era, the Belgian-based Total Football

Analysis, the Hungarian Football Factor Blog, Csakfoci, and the Sport24 section of 24.hu provided valuable information.

Hypotheses

- I hypothesize that the same tactical principles appeared in both Storck's and Rossi's approaches to building up play.
- I hypothesize that Storck's teams relied on crosses from the flanks for chance creation, while Rossi's teams emphasized individual play.

Materials and Methods

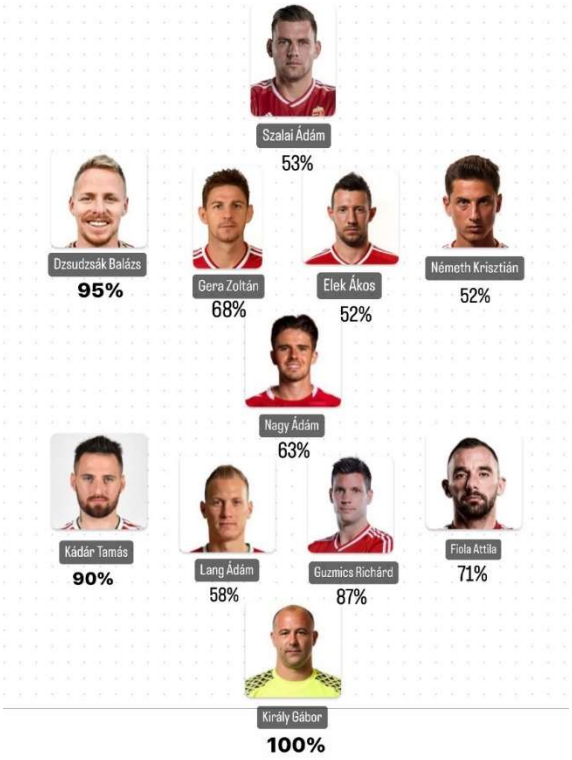
During the data collection, I aimed to gain the most comprehensive view of the strategies employed by both coaches, taking into account the playing styles observed against various opponents. I conducted a video-based analysis using footage from the Wyscout database, focusing on European Championship qualifiers, playoff matches, and tournament games for both coaches.

For Storck, this included 10 matches between 2015 and 2016, while for Rossi, I analyzed 13 matches between 2019 and 2021, covering his first European Championship qualifying period and tournament. Both teams faced opponents of similar strength, weaker teams, and stronger ones in high stakes matches.

I primarily gathered my own data but also used external sources. I conducted one-sample and two-sample t-tests to examine the results.

Results

Ball Possession Under Bernd Storck



Fihure 1: Players with the Most Minutes Played (Bernd Storck)

The figure shows the 11 players who spent the most minutes on the pitch during Storck's analyzed matches. They are placed in the most frequently used formation, 4-1-4-1, with the percentage indicating the proportion of available minutes each player spent on the field. The team played 316 minutes out of 957 in this formation. Countless publications have extensively elaborated on the intricacies and nuances of the game time change in football (Tóth Jr et al., 2023a, 2023b, 2023c, 2024)

In 8 matches, the Hungarian team displayed direct counterattacking play. We had little possession in the opponent's half, with the aim of reaching their goal with as few passes as possible.

Adam Szalai, when on the pitch, was the target man who used his physical strength to hold up the ball, lay it off, and win aerial duels. Long balls from the defense often targeted his head. (Szabó et al., 2022)

Although Storck's team generally played with four defenders, it was common (in 6 matches, a total of 23 times) to build up play with three defenders, with Ádám Nagy stepping between the center-backs 20 times. In these instances, the full-backs positioned themselves higher up the field, supporting the midfield in the wide areas, while the wingers moved closer to the central areas.

The attacking full-backs also played a crucial role in 6 matches, with the aim of overloading the flanks and creating 2v1 or 3v2 situations, followed by crosses into the box. Many publications have detailed about the importance of the attacking role of full-backs. (Tóth Jr et al., 2017, 2022a, 2022b, 2023d)

Interestingly, we can determine the expected goals (xG) for these matches and compare it with the actual goals scored: the team scored 15 goals from an xG of 11.53.

Defensive Play Under Bernd Storck

In 6 matches, we employed a mid-block, also known as mid-zone defense, occasionally pressing after the opponent's backward pass. In contrast, we defended in a deep block without pressing in 4 matches (against Greece, Norway, Portugal, and Belgium). The team conceded 15 goals from an opponent xG of 16.11.

Ball Possession Under Marco Rossi

The figure shows the 11 players who played the most minutes and the most commonly used 4-1-4-1 (or more accurately, 4-2-3-1) formation, in which the team played 530 minutes.

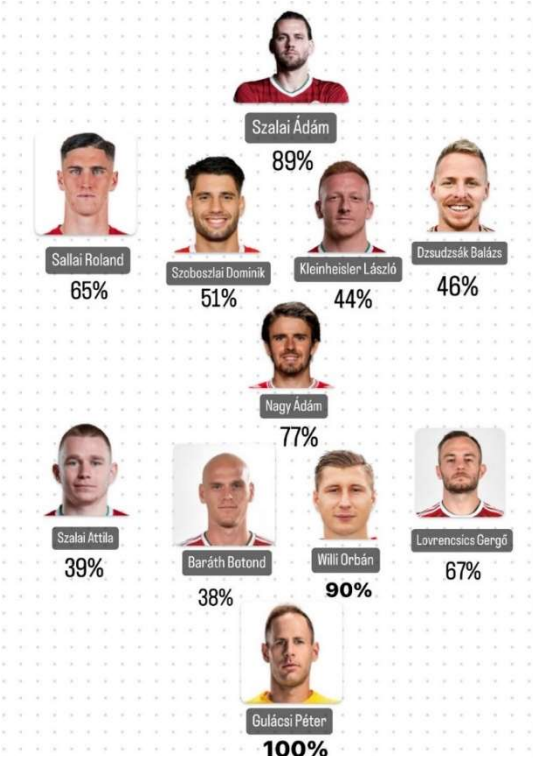


Figure 2: Players with the Most Minutes Played (Marco Rossi)

It is important to note that during Storck's time, two things were missing that were available to Rossi: VAR and the option for five substitutions. Additionally, a significant rule change altered the tactics. From the summer of 2019, the ball no longer had to leave the penalty area during a goal kick, allowing players from the kicking team to stay within the penalty box. (Kovács, 2019)

Marco Rossi aimed to organize a three-defender system, testing various formations. However, he realized after his first match that it would be more successful to revert to a four-defender system, as the right players were not available for a three-defender formation. The team played the remaining 7 European Championship qualifying matches in a four-defender system, but from the playoff match against Bulgaria onwards, Rossi returned to his three-defender system. The team often played in a 3-5-2 or 3-4-2-1 formation.

Regardless of the formation, the coaching staff's goal was to organize simpler, technically easier-to-execute attacking plays, resulting in a direct style of play. The team did not focus on possession but rather relied on long passes, often targeting Szalai, to reach the goal as quickly as possible. (Dudás, 2019)

Under Rossi, we did not focus on short-passing build-up play, despite starting the game with short passes. Instead, the aim was to lure the opponent, drawing them out and exploiting the spaces between and behind their lines with long passes or, ideally, diagonal balls. This approach is known in English as a "fake build-up," where the ball-playing is a decoy. (Marosi, 2021)

Since Rossi took over, the Hungarian team has deliberately sought to win free kicks through Ádám Szalai. The team aimed to capitalize on set-pieces or shots near the penalty area. This is reflected in the statistics, as we scored the most goals from set-pieces during this period, precisely 7 goals. (Ramesh, 2021)

Interestingly, we can determine that we scored 16 goals from an xG of 12.92.

Defensive Play Under Marco Rossi

In 10 matches, we played without the ball in a mid-block, and in 3 matches (against Portugal, France, and Germany), we defended in a deep block. The team conceded 19 goals from an opponent xG of 20.52.

Tactical Characteristics

It can be stated that both eras featured direct counterattacking football. Both coaches to build up play with three defenders. While Storck occasionally switched to this approach during matches from his four-defender system, Rossi used it as his base formation. Our target man, the strong center-forward Ádám Szalai, played a key tactical role: we deliberately aimed long balls at him (85% of such passes under Rossi). The emphasis, therefore, is on intentionality.

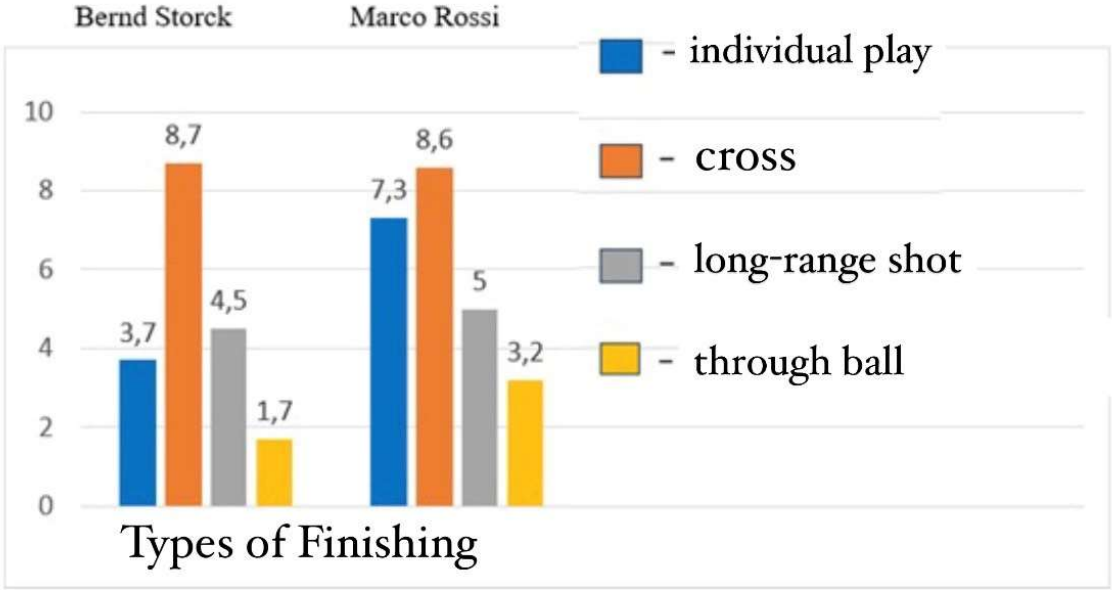


Diagram 1: Types of Finishing (Bernd Storck vs. Marco Rossi)

From the finishing types diagram, another similarity can be seen: both teams frequently utilized crosses. A tactical difference is also evident: Rossi relied heavily on individual play, breaking down the opposition with attacking duels. The reason for this difference is that Rossi had the right players for it: Roland Sallai and Dominik Szoboszlai.

Another difference, not visible on the diagram but clear from the match analysis, is set pieces. The deliberate winning of free kicks and their exploitation was only effective under the Italian coach.

Conclusion

To validate my first hypothesis, I conducted two independent two-sample t-tests on the long-ball build-ups of Storck's and Rossi's teams and the number of passes in both eras. Based on the tests and match analyses, my first hypothesis was confirmed.

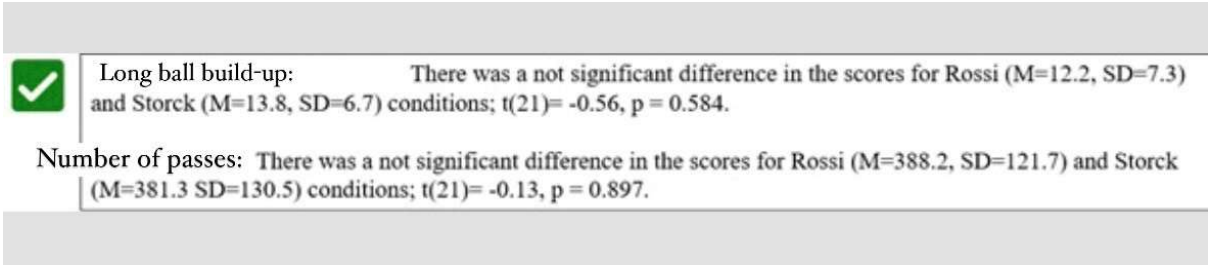


Figure 3: First hypothesis test

My second hypothesis was also confirmed, supported by two one-sample t-tests on the number of crosses and the emphasis on individual play

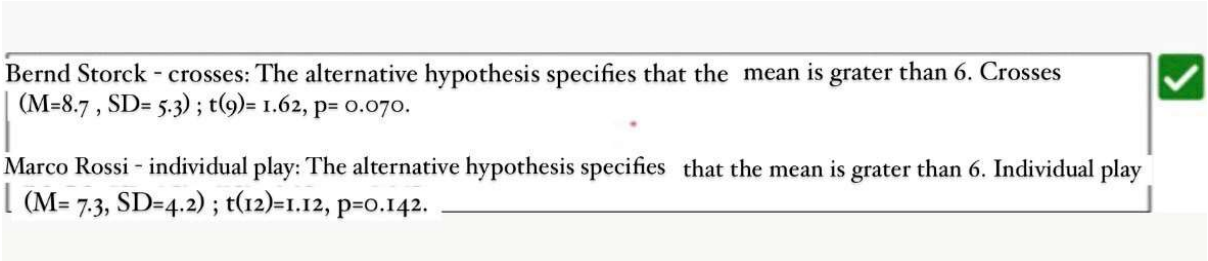


Figure 4: Second hypothesis test

Conclusion

To continue achieving success, the Hungarian national team needs a tactical approach where the goals and methods to achieve them are precisely defined for each phase of the game, with clear instructions for the roles each player must fulfill. However, it is also crucial to have players who can play freely, relying on their creativity and unpredictability to cause problems for the opposition defense. The analysis results highlight that future success will depend on building on proven tactical elements while also incorporating innovative solutions into the team's play.

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Correlations Between the Illinois Agility Test with a Ball and Match Evaluations

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Introduction

In today's world, player observation heavily relies on tests and statistics, which form the first impression of a footballer. One of the coaches' responsibilities is to prepare match evaluations based on various criteria. But how accurate are these evaluations in reflecting a player's true capabilities? Is there any subjective bias in the assessments?

In my research, I aimed to find correlations between the average results of Illinois agility tests conducted with three age groups at the Hungarian Football Academy and the average match ratings of the players who participated in the tests over ten matches.

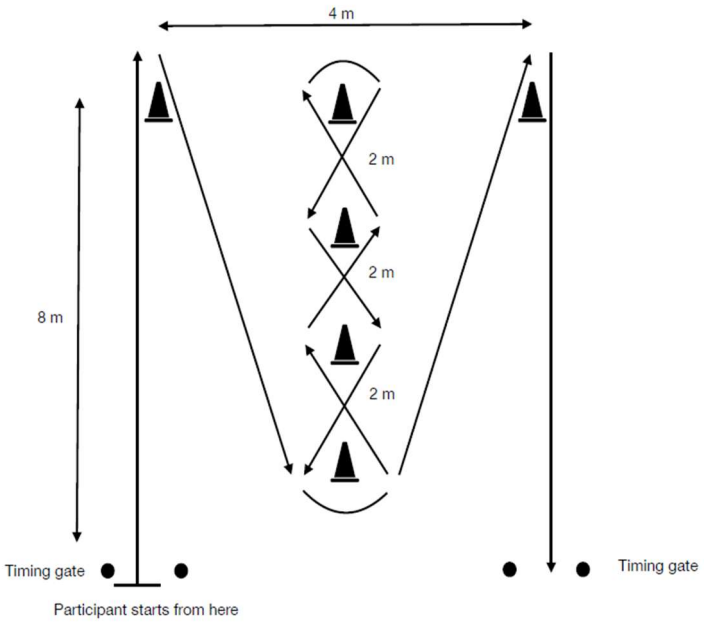
Reason for Topic Selection

Why did I choose this topic? It is a football-specific subject, and I found it intriguing to compare a subjective evaluation with an objective, concrete test result. Additionally, I was motivated by the fact that, to my knowledge, no one has conducted similar research before.

Hypotheses

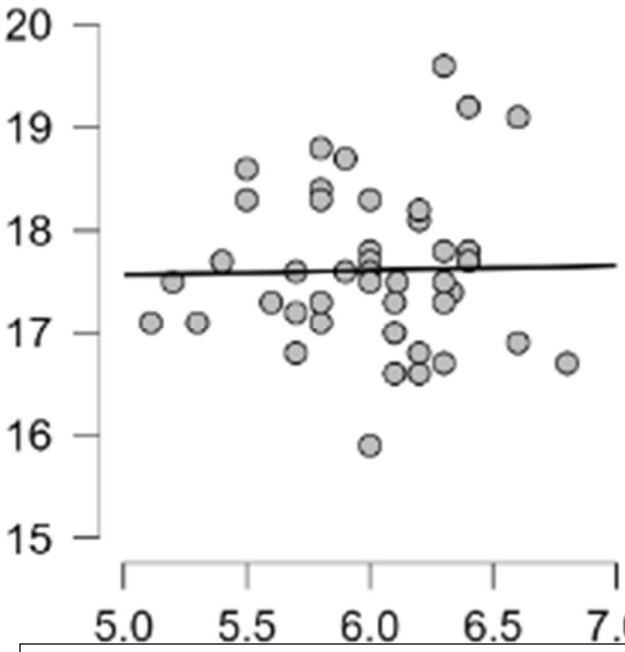
I formulated two hypotheses:

1. In my first hypothesis, I assumed that players who achieved outstanding results in the test would also excel in the average match ratings, while those who performed below average in the test would produce similar results in their matches, according to their coach.
2. In my second hypothesis, I assumed that there would be a significant difference between the results of older and younger players in both aspects.



1. illustration: Modified Illinois test

Materials and Methods



2. Illustration: The result of

The experiment involved the youth players (U12-U14) of Budapest Honvéd FC, who underwent a ball-handling test on a modified Illinois course. In my research, I analyzed the results of the players who participated in the test and compared them with their match evaluations obtained using the Talent-X program.

The modified Illinois test was conducted on an 8x4 meter course, compared to the original 10x5 meter course. Each age group took the test on different

days. Each player completed two practice runs and then ran the course five times, with the average time of these five runs being used for all 44 subjects.

In the Talent-X program, I used the average of the ten-match evaluations for each player who participated in the Illinois test.

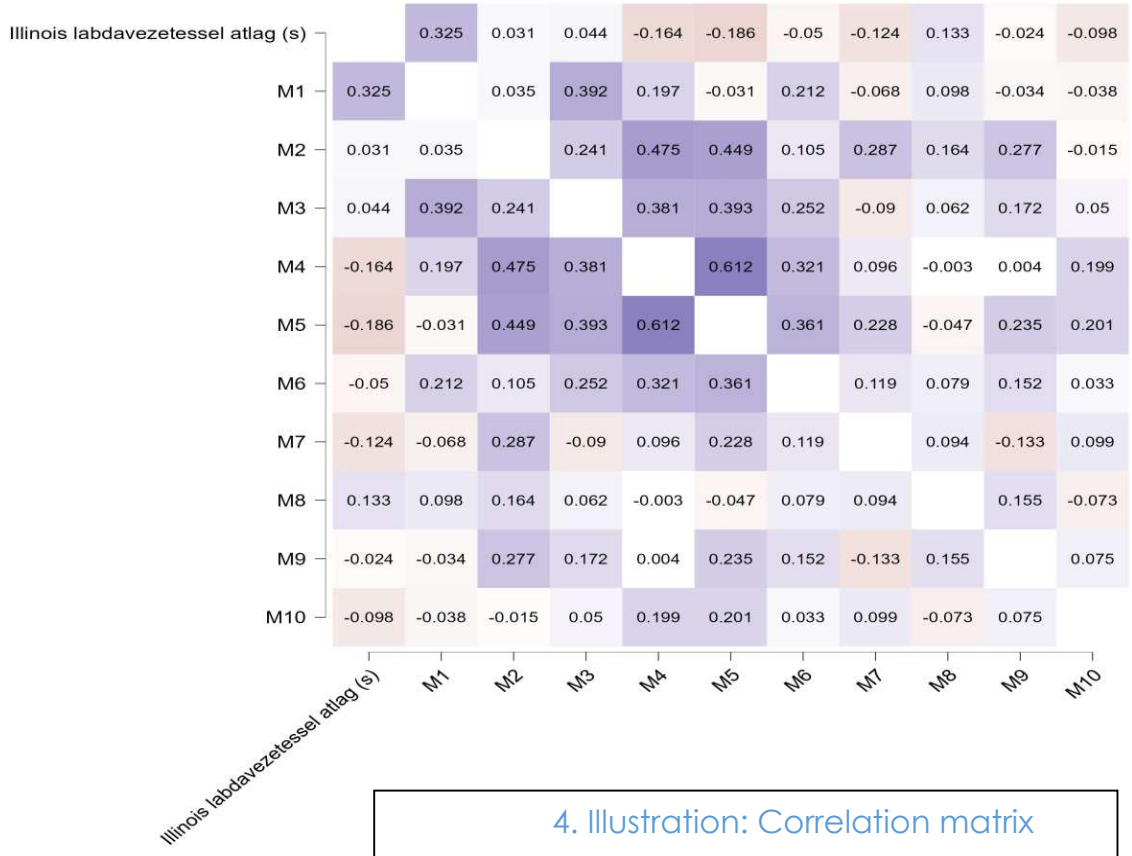
3. Illustration: P-value of the Colleration

	Illinois labdavezetessel atlag (s)
Pearson's r	—
p-value	—
Spearman's rho	—
p-value	—
Kendall's Tau B	—
p-value	—
Pearson's r	0.022
p-value	0.885
Spearman's rho	−0.021
p-value	0.892
Kendall's Tau B	−0.018
p-value	0.871

To examine my first hypothesis, I employed correlation analysis. Correlation analysis indicates whether there is a cause-and-effect relationship between two independent variables. If the values of the variables align on an imaginary straight line, we can speak of a correlation.

Since one of my variables was ordinal, I had to consider Kendall or Spearman correlations, as well as their p-values. I created a correlation matrix that visually represents how the Illinois test results correlate with each match. The darker the shade of blue in a cell, the stronger the correlation.

For the examination of my second hypothesis, I used variance analysis and conducted a Post Hoc test.



4. Illustration: Correlation matrix

Other's testing methods for soccer players' performance, agility, and matches:

Match Analysis:

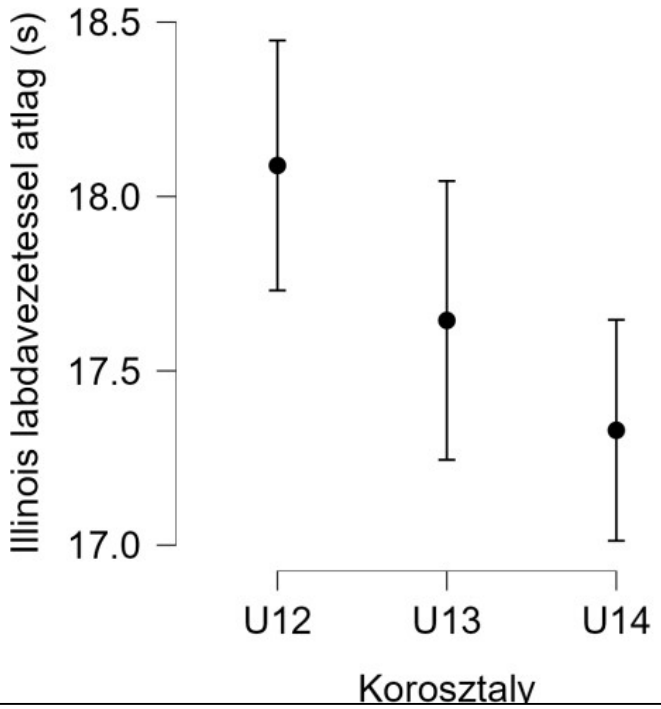
- Zalai (2016) used Prozoner technology, an internationally recognized tool for the quantitative analysis of matches, providing objective data on players' performance, such as running distances, speed, and positioning.
- In my research, the evaluation was based on the subjective opinions of the coaching staff, which allows for the incorporation of professional expertise and knowledge of game-specific situations. While this type of evaluation may offer more personalized insights, it provides less objective, quantifiable data.
- Countless publications have data on the analysis of multiple matches by different factors.(Tóth Jr et al., 2023a, 2023b, 2023c, 2024)

Performance Measurement:

- In Kovács M. (2020)'s experiment, players received instructions from a display and a machine, and they had to navigate specific routes as quickly as possible, focusing on reaction time and fast decision-making.
- In my research, the modified Illinois test required movements to be performed with the ball, which is more relevant from a football perspective, as ball handling and movement speed are critical. Therefore, your test better reflects football-specific requirements.

Agility:

- In Matlák János (2018)'s study, agility testing was combined with reaction time measurement, as players had to respond to flashing lights.
- In my research, the focus was solely on ball-based agility, a particularly important aspect of football. The use of photocells at the end of the course provided accurate time results, but agility in this case was closely intertwined with ball handling.



2. Illustration: Result of Variation

From the interval chart prepared for my second hypothesis examination, we can conclude that only the players in the U12 and U14 age groups showed a significant difference, as indicated by the Turkey p-value obtained in the post hoc test.

Conclusion

As we can see from the correlation chart used in my first hypothesis examination, the players' values do not align on the so-called imaginary line. Based on the p-values of the Kendall and Spearman correlations, we can conclude that there is no correlation between my two variables.

5.Illustration: The result of variance analysis

Post Hoc Comparisons - Korosztaly ▼

		Mean Difference	SE	t	p_{tukey}
U12	U13	0.444	0.301	1.478	0.312
	U14	0.759	0.304	2.501	0.043
U13	U14	0.315	0.249	1.265	0.423

6. Illustration: Post hoc test

Based on the variance analysis and post hoc test of the match evaluations, it is visually apparent that there is no significant difference between the evaluations of the different age groups.

Summary

Based on the conducted analyses, I concluded that:

1. My first hypothesis, which stated that "Players who achieved outstanding results in the test also excelled in their match ratings, while those who performed below average in the test also produced similar results in their matches, according to their coach," was not confirmed.
2. My second hypothesis, which stated that "There is a significant difference between the results of older and younger players in both aspects," was also not confirmed based on the conducted analyses.

Recommendations

For future research, it would be beneficial to compare the result of the Illinois test with Zig-Zag test, for instance Do the children have better match evaluation with the Zig-Zag test or not.

We would be research that with which test they develop the most.

I would like to read as many articles related to my research as possible in the future.(Tóth Jr et al., 2017, 2022a, 2022b, 2023d)

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Effectiveness of Chelsea's Lineups in the Last 5 Seasons

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Introduction

Our topic examines the five, four, or even three-defender formations used by Chelsea in recent seasons. The team has seen many coaches over the past five seasons, each favoring different playing styles. Consequently, we must also consider who occupied the Chelsea bench during this period, which formations they employed, and how successful each coach was with their preferred five-, four-, or three-defender setups.

Justification for Topic Selection

Chelsea FC has employed five, four, or even three-defender formations over the past five seasons. Consequently, we decided to demonstrate how effectively the club has performed in recent seasons through the frequent variation of these lineups. The frequent changes in coaching staff and playing styles warrant an analysis of the effectiveness of these formations in achieving the team's objectives (Tóth et al., 2023; Klink et al., 2023).

Materials and Methods

Our research was conducted based on videos and notes from the team's matches. We analyzed match outcomes, possession rates, goals scored, and goals conceded to evaluate the impact of different formations used by Chelsea across various seasons (Tóth et al., 2023; ifj. Tóth et al., 2017).

Research Hypotheses

Hypothesis 1: In a four-defender system, Chelsea was able to maintain greater possession of the ball compared to a three-defender system.

Hypothesis 2: In a five-defender system, they conceded an average of fewer goals per match than in a four-defender system.

Hypothesis 3: In a three-defender system, they scored an average of more goals per match than in a four-defender system.

Results by Season

2018/19 Season

In the 2018/19 season, Maurizio Sarri was the coach, who preferred a four-defender system, with the most frequently used formation being 4-3-3. The team was characterized by high pressing, an advanced defensive line, ball possession, and quick ball circulation. Over the course of 61 matches, Chelsea achieved 39 wins, 12 draws, and 10 losses. In these matches, Chelsea scored 112 goals, while conceding 56. The team's possession rate was 64.7% (M4 Sport, 2021). Thanks to this style of play, Chelsea finished the league in 3rd place, reached the final of the League Cup, advanced to the 5th round of the FA Cup, and won the Europa League.

2019/20 Season

In the 2019/20 season, Chelsea was under the management of Frank Lampard, who frequently employed multiple formations in both three- and four-defender systems, enjoying the variation. In the four-defender system, he focused on ball possession and attacking play, allowing Chelsea to widen their game and create more opportunities for deep passes. Defensively, they compacted the space and often won the ball in the middle third due to their aggressive pressing. With the three-defender system, Chelsea produced a more disciplined style of play. During this season, Frank Lampard managed 54 matches, achieving 30 wins, 9 draws, and 15 losses. In these matches, Chelsea scored 100 goals and conceded 80, with an average possession rate of 58.95%. Based on these results, Chelsea finished 4th in the league, reached the final of the FA Cup, and made it to the Round of 16 in both the League Cup and the Champions League (Sofascore, n.d.).

2020/21 Season

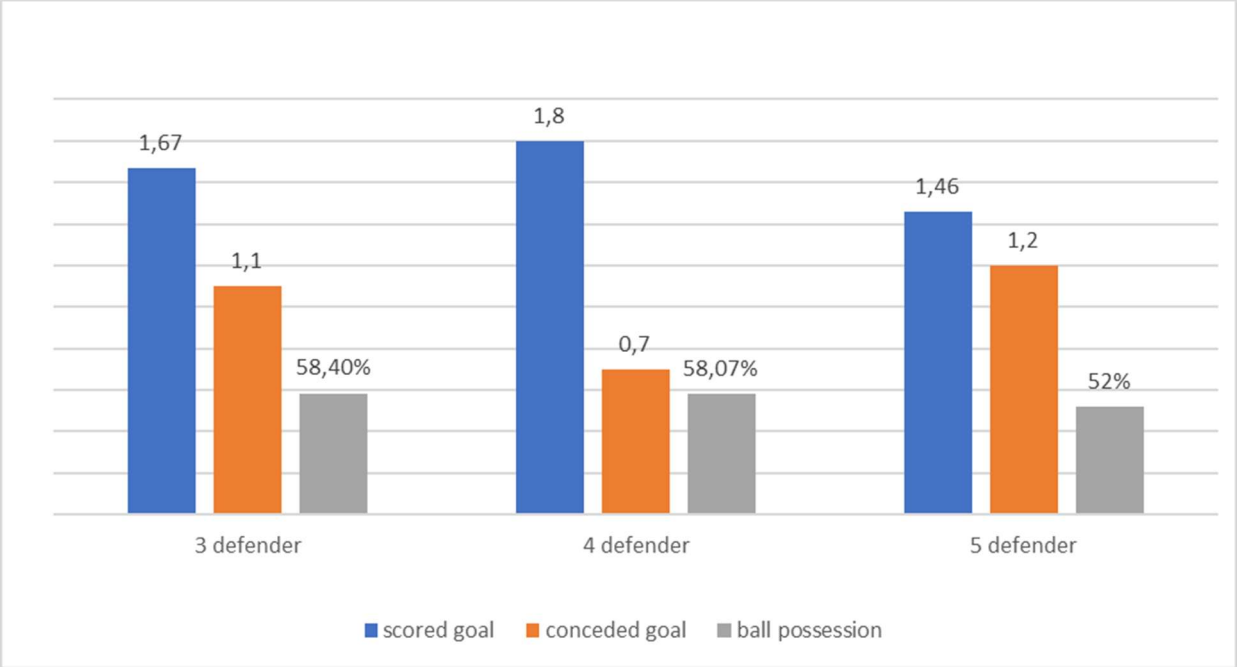
The 2020/21 season began with Chelsea still under Frank Lampard's leadership. This first half was characterized by numerous beautiful elements of play, but it yielded fewer results, partly due to defensive errors and partly due to Lampard's intense style of football. There were no significant formation changes compared to the previous season, although a few occurred in certain matches. Alongside the tried-and-true 4-2-3-1 formation, the introduction of the 3-4-2-1 setup was seen as a way for new stars to easily find their place. Chelsea played 29 matches (16 wins, 7 draws, 6 losses), scoring 57 goals and conceding 27, while averaging 57.5% possession. However, the League Cup ended in the Round of 16. By the end of the first half of the season, a series of losses led to the termination of Lampard's contract. Thomas Tuchel took over in the second half, deploying 3-4-2-1 and 5-2-3 formations. With Tuchel, Chelsea became a much more tactically mature team, pushing the lines higher and expecting quick pressing from players. In the second half, Chelsea achieved impressive results, playing 31 matches (20 wins, 6 draws, 5 losses), scoring 38 goals and conceding 16, with an average possession rate of 59.4%. They secured 4th place in the league, reached the FA Cup final, and won the Champions League under Tuchel's leadership (The Mastermind Site, 2023).

2021/22 Season

In the 2021/22 season, Tuchel managed Chelsea, deploying the familiar 3-4-2-1 and 5-2-3 formations, as well as using 4-2-3-1 and 4-4-2 setups. The team’s style did not change significantly; they continued to push the lines higher and press opponents quickly. Chelsea played 60 matches (36 wins, 14 draws, 10 losses), scoring 118 goals and conceding 34, with an average possession rate of 63% (ifj. Tóth et al., 2013). They finished 3rd in the league, reached the finals of both the FA Cup and League Cup, but failed to defend their Champions League title, being eliminated in the quarter-finals.

2022/23 Season

The 2022/23 season began with Tuchel still at the helm. Chelsea did not start the season well, recording three wins, one draw, and two losses in the first six rounds of the Premier League, along with a disappointing defeat in Zagreb. Following these results, Tuchel was dismissed and replaced by Graham Potter. Potter quickly gained sympathy for his possession-based, combinational style of play. However, there were drawbacks: the team tended to slow down as they reached the opponent's goal, leading to a dominance in possession that did not always result in dangerous chances. Throughout the season, Potter deployed 4-2-3-1 and 3-4-2-1/5-2-3 formations, resulting in 31 matches (11 wins, 9 draws, 11 losses), scoring 31 goals and conceding 30, with an average possession of only 50.9%. They reached the 3rd round in both the FA Cup and League Cup, leading to Potter's dismissal. By the end of the season, Frank Lampard returned to manage the team, but he could not turn things around, recording 1 win, 2 draws, and 8 losses over 11 matches, scoring only 9 goals and conceding 21, with an average possession rate of 52.5%. In the Champions League, they reached the quarter-finals, finishing 12th in the league, their worst position in the last five seasons (ifj. Tóth & Tóth, 2022).



Conclusions and Recommendations

Based on the results shown in the column chart, our first hypothesis—that Chelsea was able to maintain a higher possession rate in a four-defender system than in a three-defender system—was confirmed.

Our second hypothesis—that in a five-defender system, they conceded an average of fewer goals per match than in a four-defender system—was not confirmed.

Additionally, our third hypothesis—that in a three-defender system, they scored an average of more goals per match than in a four-defender system—was also confirmed.

In the future, we would like to examine the average percentage of ball recoveries in the defensive, midfield, and attacking thirds, as well as the percentage of ball possession.

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The Significance of Ball Possession in Determining Match Outcomes

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Introduction

In the world of football, opinions and views on this topic are frequently discussed. Common statements like "We were the better team, but we lost," or "We had the ball the whole time, but still lost," often arise. The aim of my research is to shed light on the relationship between ball possession and match outcomes, thereby exploring the significance of ball possession in football.

Literature Review

In my research, I relied on several articles. Four articles from Hungarian websites helped my investigation. These include *Bazfoci*: "The Key to Victory in Football", *Büntető.com*: "What Can We Learn from Bielsa?", *magyarfutball.hu*: "How Has Football Changed Over the Past 50 Years?", *Eurosport*: "More Passes, Fewer Shots". Our research involved consulting multiple academic articles, including studies titled: (Tóth J. jr, Jávorcsík G, Tóth J, 2023); (Klink Z, Tóth J. jr, Tóth J, Prukner L. 2023); (Tóth, Tóth J. jr, 2022); (Tóth J. jr, Vereckei Z, Tóth J, 2020); (Tóth J. jr, Tóth J., 2018); (Pichler R, Tóth J. jr, Tóth J, 2017); (Berta J, Tóth J. jr, Tóth J, 2017); (Papp K, Szekeres L, Tóth J. jr, Tóth J. 2017); (Sütő K, Blázsovics Á, Tóth J. jr, Tóth J, 2017); (Gucsi Végh P, Tóth J. jr, Tóth J, 2016); (Tóth J. jr, Zalai D, Tóth J, Hamar P, 2013); (Tóth J. jr, Tóth J, Hamar P, 2012); (Tóth J. jr, Csáki I, Tóth J, 2012); (Tóth J. jr, Tóth J, Hamar P, 2011).

Hypotheses

- I hypothesize that in the group stages of the mentioned tournaments, teams with higher ball possession will win more often than in the knockout stages.
- I hypothesize that in the knockout stages of the mentioned European Championships, teams with higher ball possession will advance more frequently than in the World Cups.
- I hypothesize that the tournament winners had higher ball possession in 75% of their matches compared to their opponents.

Materials and Methods

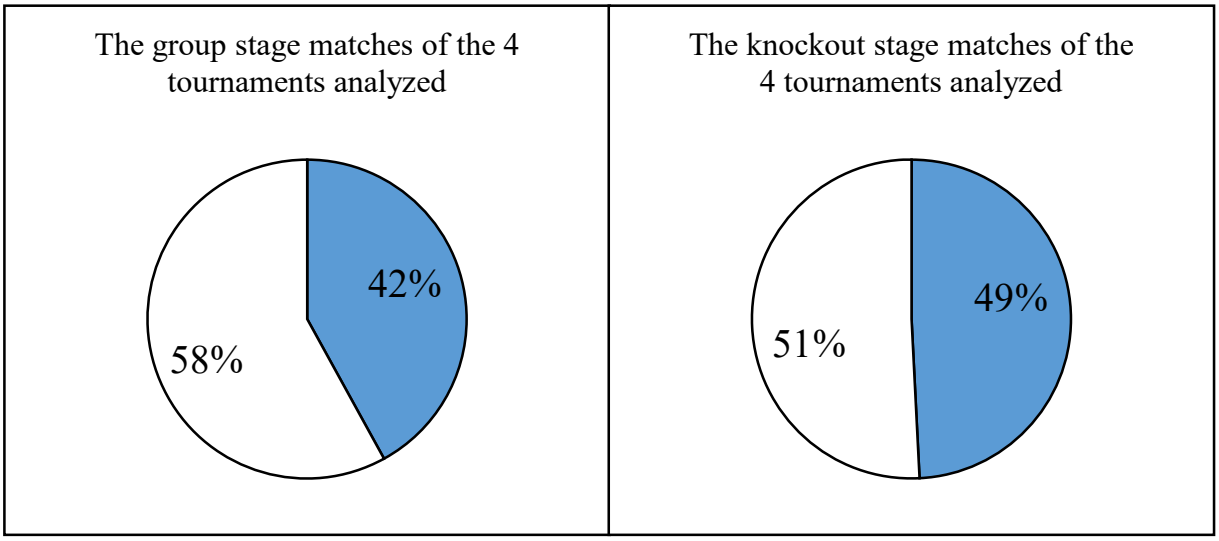
My study focused on ball possession rates and match outcomes. I conducted data analysis and ratio calculations. I examined the matches from the 2016 and 2021 European Championships and the 2018 and 2022 World Cups, using data from eredmenyek.com, covering 230 matches. However, in four instances, ball possession was recorded as 50-50%, so I excluded those, leaving 226 matches for analysis. In the knockout stages, I considered the advancing team as the winner.

Results

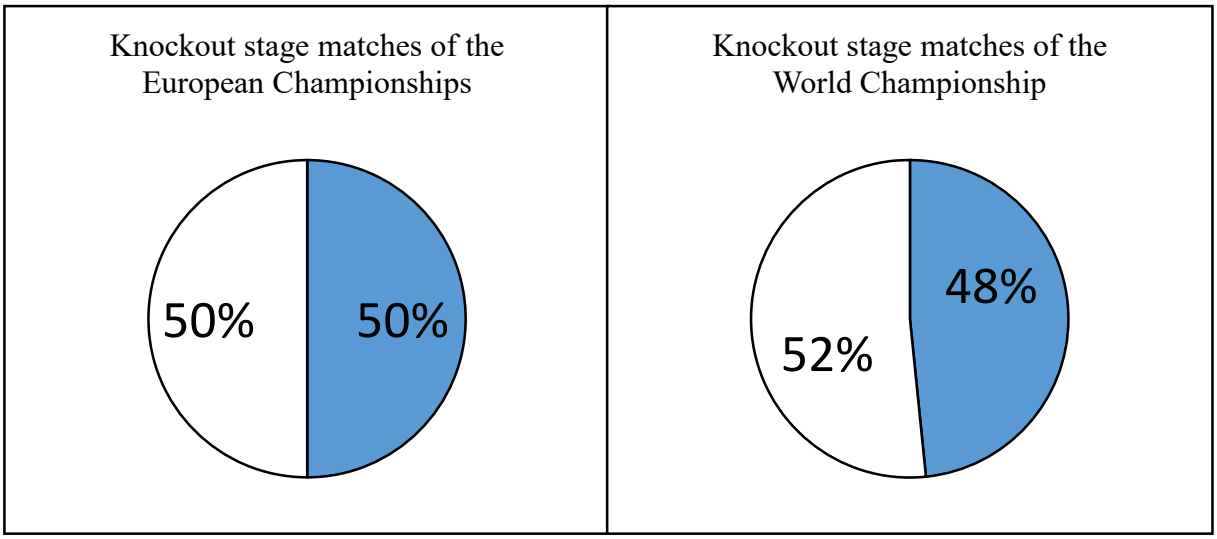
My research was based on the hypotheses, analyzing the outcomes from the perspective of the team with higher ball possession. First, I compared the data from the group matches and knockout stages of the studied tournaments. I sought to determine in which phase teams with higher ball possession were more successful.

In the 165 group matches, the team with more ball possession won 69 times, representing 42% of the matches. In the 61 knockout matches, the team with more ball possession won or advanced 30 times, accounting for 49%. These data are presented in pie charts.

3. diagram – group stage and knockout stage matches, blue: matches won, white: matches lost



In the second part of my research, I examined the knockout matches of the mentioned tournaments. I was curious to see if the team with higher ball possession advanced more often in the knockout stages of European Championships or World Cups. In the European Championships, 15 of 30 matches saw the advancing team hold more possession, representing 50%. In the World Cups, 15 of 31 matches saw the team with higher possession advance, which represents 48%. These data are also shown in pie charts.



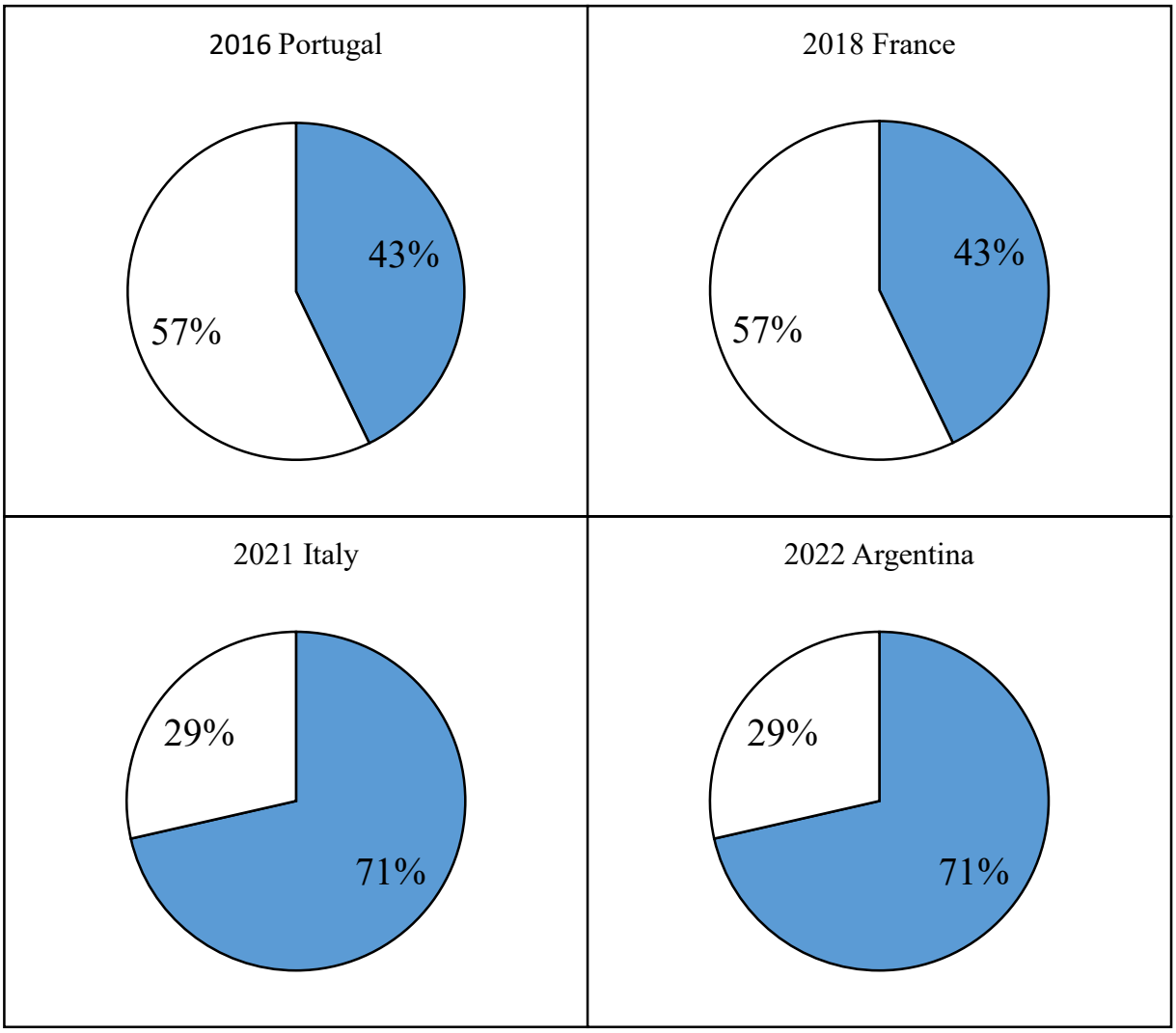
4. diagram – Knockout matches of the European and World Championships, blue: advanced to the next round, white: eliminated

In the third and final phase of my research, I analyzed the tournament winners. I examined their matches based on ball possession. Each tournament winner played seven matches. My question was, how often did the tournament winners have higher ball possession than their opponents? Portugal, the 2016 European champion, had more ball possession in three of their seven matches, accounting for 43%. Interestingly, Portugal had more possession in all their group matches but less in each of their knockout matches.

France, the 2018 World Cup winner, similarly had more possession in only three matches, again representing 43%.

Italy, the 2021 European champion, had more possession in five of their seven matches, representing 71%.

Argentina, the 2022 World Cup winner, also had more possession in 71% of their matches. From these results, we can conclude that in the two tournaments before 2020, teams relying on counter-attacks were more successful. However, since 2020, teams focusing on ball possession have been more successful.



5. diagram – matches of the championship winners, blue: had more possession, white: had less possession

Conclusion

My first hypothesis, which suggested that teams with higher ball possession would win more often in group stages than in knockout stages, was not confirmed, as teams with more possession won more in knockout matches.
My second hypothesis, which proposed that teams with more possession would advance more frequently in the European Championships compared to the World Cups, was confirmed.
My third hypothesis, that tournament winners would have higher possession in 75% of their matches, was not confirmed, as none of the winners had more possession in 75% of their matches.

Final Thoughts

My research highlighted the different playing philosophies emerging in various periods. Further analysis of more European and World Cups is needed to continue this study. Afterward, I can further investigate the tactical principles and trends of these periods.

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