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Running Performance of Physical Education and Sports Students: A Longitudinal Descriptive and Multivariate Analysis

Rendimiento en Carrera de Estudiantes de Educación Física y Deportes: Un Análisis Descriptivo Longitudinal y Multivariado

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SUMMARY: Monitoring running performance provides important insight into physiological development, training effectiveness, and individual differences in speed and endurance, as sprint and middle-distance events require different contributions of anaerobic and aerobic capacities. The aim of this study was to analyze generational differences and interrelationships in performance across short- and middle-distance events among twelve generations (groups) of students. The longitudinal study included 210 third-year students from the faculty of Physical Education and Sport over a 12-year period, and performance was assessed in the 100 m, 200 m, 400 m, and 800 m events under standardized conditions. Statistical analysis included descriptive statistics, tests of normality and homogeneity, Pearson correlation coefficients, MANOVA, and univariate ANOVA with Tukey HSD post hoc tests. MANOVA revealed statistically significant differences among generations in overall performance (Wilks' Lambda = 0.481; F = 3.44; $p < 0.001$; $\eta^2 = 0.519$), while univariate ANOVA identified significant differences only in the 100 m event (F = 4.767; $p < 0.001$; $\eta^2 = 0.212$). All events were positively and statistically significantly correlated, with the strongest correlation observed between the 100 m and 200 m ($r = 0.799$; $p < 0.001$), and moderate correlations between the 100 m and 800 m ($r = 0.542$), 200 m and 400 m ($r = 0.686$), and 400 m and 800 m ($r = 0.666$) (all $p < 0.001$). Middle-distance performances showed relative homogeneity across generations, whereas sprint performances demonstrated greater variability, indicating that generational differences are most pronounced in short sprint events. Sprint performance partially predicts middle-distance results, confirming the interaction between speed and endurance capacities and emphasizing the importance of continuous performance monitoring and training adaptation to the specific demands of each discipline.

KEY WORDS: Running; Middle-distance; Student performance; Multivariate analysis.

INTRODUCTION

Athletics represents a fundamental sports discipline that encompasses basic human motor skills, among which running occupies a central position in terms of human development and functional efficiency. It integrates the largest number of basic motor abilities and plays a key role in the system of physical education and sport (Pérez Hernández *et al*., 2022; Jefferson-Buchanan, 2022; Garbeloto *et al*., 2025). Running has significant application in everyday functioning, standing out as a basic form of locomotion and the most common form of structured physical activity across different populations. Positive effects on the cardiovascular system have been demonstrated, while short sprinting exercises and explosive drills influence the development of neuromuscular mechanisms important for achieving high running speeds (Kozina *et al*., 2018, 2020; Da Rosa *et al*., 2019).

Sprint athletic disciplines, including short and long sprints (100 m, 200 m, 400 m) and middle-distance running (800 m), involve a complex interaction of physiological, biomechanical, psychological, and environmental factors in young runners that enable individual success (Blagrove *et al*., 2018; Sandford *et al*., 2019a; Sandford *et al*., 2019b). Sprint disciplines are characterized by relevant parameters based on morphological, functional, and motor dimensions. In these disciplines, particular emphasis is placed on leg muscle strength, the volume and girth of the thigh muscles (Llanos-Lagos *et al*., 2024), and functional capacities related to anaerobic capacity (Bachero-Mena *et al*., 2017), which implies the activation of phosphocreatine and glycolytic processes, whereas middle-distance running involves a combination of glycolytic and aerobic energy processes.

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Sustainable running performance depends on a complex interaction of factors that lead to efficient muscle function and should result in a fast and efficient running gait (Balsalobre-Fernández *et al*., 2016; Govindasamy *et al*., 2023). Among the factors that can predict performance in middle-distance running events such as the 800 m is running economy, which is commonly defined as a stable factor essential for success and as the amount of oxygen consumption (VO^2) required at a given submaximal speed. These performance determinants have attracted increasing attention over the past decade, although they are still often referred to as being "relatively neglected in the scientific literature." Traditionally, biomechanical factors (Santos-Concejero *et al*., 2014), muscle fiber distribution (Pellegrino *et al*., 2015), age and sex (Balsalobre-Fernández *et al*., 2016), and anthropometric factors explain interindividual variability in running economy and the achievement of high-performance results. It should not be overlooked that sprint performance and the homogeneity of results within a given group of athletes are also strongly influenced by sex and age as primary factors determining sporting performance, due to fundamental sex-based differences in anatomy and physiology dictated by sex chromosomes and sex hormones (Hunter *et al*., 2023). Relatively high speeds achieved in middle-distance and longer track events, particularly among younger runners, require high mechanical power output, even though ground reaction forces are lower than in sprinting (Bahensky *et al*., 2020), which is also a shared characteristic of short-distance running (such as the 100 m) and middle-distance events (such as the 400 m or 800 m). The technique of force application is a decisive factor in sprint performance, unlike the total amount of force that individuals can apply to the ground (Morin *et al*., 2011). It appears that the orientation of the total force applied to the ground during acceleration and sprinting is more important for performance outcomes than its magnitude. However, sprint and middle-distance running performance is also strongly influenced by training strategies, including a wide range of strength-training modalities such as low-load training, high-load training, explosive training, and plyometric training (Barnes & Kilding, 2015; Govindasamy *et al*., 2023). It has been demonstrated that these different strength-training modalities improve running economy in recreational, moderately trained, and highly trained runners. According to the scientific literature, training aimed at developing maximal force yields the best results in improving running speed in sprint and middle-distance events (Beattie *et al*., 2014).

The maximal running speeds observed in sprint disciplines (100 m and 200 m) and middle-distance events (400 m, 800 m) are achieved through high vertical ground reaction forces applied over very short contact times (Gupta *et al*., 2021; Lin *et al*., 2023). When generating maximal power output, sprint disciplines rely heavily on anaerobic energy mechanisms (Haase *et al*., 2025), as well as on a large number and large cross-sectional area of type II muscle fibers in the leg muscles (Thompson, 2017). Performance in middle-distance runners is characterized by interacting biomechanical and physiological parameters (Tschopp & Brunner, 2017; González-Ravé *et al*., 2021; Rivera-Kofler *et al*., 2024), with the possibility of unique combinations of each leading to high levels of performance. Performance in middle-distance events is associated with a range of factors, including maximal oxygen uptake (VO^{2}max), velocity at VO^{2}max (vVO^{2}max), maximal metabolic steady state, running economy, and sprinting abilities. Research also indicates a significant decline in speed and an increase in oxygen consumption during the final phases of 400 m and 800 m races, reflecting a complex interaction between aerobic and anaerobic processes during maximal effort (Bachero-Mena *et al*., 2017; Campos *et al*., 2022; Thurlow *et al*., 2024; Belechris *et al*., 2025). In addition, performance in the 800 m event shows a strong association with sprint and explosive abilities, confirming the need for a multivariate approach in the analysis of running performance.

Previous research indicates that performance in sprint disciplines depends on numerous factors, including running technique, the training process, level of training, generated force output, sex, age, as well as other biological and functional variables. Running performance is a key indicator of physical fitness and athletic potential in students of Physical Education and Sports. Although asymmetry between sprint performance and long-distance running is well documented among elite athletes, it remains unclear whether similar patterns occur in populations of students of physical education and sport. In particular, the relationship between performance outcomes across different running distances has not yet been fully clarified, especially in individuals with basic or intermediate levels of running ability. Given the central role of running in athletics and its importance for most sports disciplines, the examination of running performance among students of physical education and sport represents an important basis for understanding the development of motor abilities and for planning effective training and educational programs for future professionals in the field of physical education and sport. Although there is a rich body of research focused on elite athletes, little is known about the manifestation of these patterns among students, who are generally expected to have intermediate or basic levels of running ability. Students of faculties of physical education and sport constitute a specific population that combines an adequate level of general and specific running abilities with the potential influence of a modern sedentary lifestyle. Monitoring running performance across multiple student generations enables insight into longitudinal changes, as well as the stability of relationships between different running disciplines. Therefore, longitudinal and multivariate investigations are essential for understanding the legality governing the development of running abilities, the interrelationships among performance outcomes across different distances, and their application in sport, education, and everyday life. It is particularly unclear how performance across different running distances correlates with each other and how it develops over time. Longitudinal monitoring allows for the analysis of changes and the stability of running abilities, while multivariate analysis enables an understanding of the complex interaction of factors that influence success in running.

The aim of the study is to analyze variations and relationships in running performance among generations of students at the Faculty of Physical Education and Sport in the 100 m, 200 m, 400 m, and 800 m disciplines, using descriptive and multivariate statistics. The following hypotheses were formulated:

1. There are significant differences in running performance of students in the 100 m, 200 m, 400 m, and 800 m disciplines across generations.
2. Performance in shorter disciplines (100 m and 200 m) positively correlates with performance in longer sprint and middle-distance events (400 m and 800 m).
3. The variance of running performance among generations is homogeneous, allowing valid comparison of results.

MATERIAL AND METHOD

Sample od participants

A total of 210 male students in their third (III) year at the Faculty of Physical Education and Sport, University of East Sarajevo, aged 20 to 25, participated in this longitudinal study conducted over twelve years. Measurements were taken during the practical exam of the Athletics course, ensuring a high level of participant motivation since the results had direct academic significance. All participants provided informed consent prior to the study and met basic health and functional criteria necessary for the safe execution of physiological tests. Participants had a certain level of prior training experience, which enabled valid and comparable measurements.

The Ethics Committee of H.S. Skovoroda Kharkiv National Pedagogical University was given permission to conduct this research, as it complies with the Declaration of Helsinki of the World Medical Association - ethical principles of medical research involving human subjects (No. KhNPU/PhES/EC/12/12/2011). The experiment was carried out beginning December 12, 2011 and ended November 25, 2024.

Inclusion criteria

Participants were included if they:
- Were male,
- Were third-year students at the PES,
- Were in good health and had the functional capacity to safely perform physical tests,
- Participated in the practical part of the Athletics exam as part of the regular curriculum.

Exclusion Criteria
- Had health or functional impairments that could prevent the safe execution of physical tests,
- Did not regularly attend practical Athletics classes or did not participate in official testing during the exam,
- Had inconsistencies in measurement results or incomplete data.

Research design

Instruments and Procedures. The tests were conducted under standardized conditions on an athletic track, in accordance with the official IAAF rules. Prior to testing, all participants performed a standardized warm-up lasting 10–15 minutes, which included light jogging, dynamic stretching, and running preparation exercises, aimed at preparing the musculoskeletal system and reducing the risk of injury. All participants were tested in four running disciplines: 100 m, 200 m, 400 m, and 800 m. The tests were conducted during the practical examination for the Athletics course, with participants performing a maximum of one or two disciplines per day to preserve physiological freshness and ensure the validity of results. A rest period of 20–30 minutes was provided between individual disciplines to minimize fatigue effects and maintain the reliability and representativeness of running performance indicators. Race times were measured manually by the same experienced measurer for all tests to ensure objectivity and reduce subjective error. The tests were carried out under standardized conditions (no rain, minimal wind) with a high level of intrinsic motivation.

Data Processing and Statistical Analysis

The collected data were processed using the Statistica 10.0 software package. To describe central tendency and variability of performance within and between generations, basic descriptive statistical parameters were calculated, including the mean (Mean), standard deviation (SD), minimum (Min) and maximum (Max) values, range (Range), confidence interval (CI ± 95 %), standard error (SE), and coefficient of variation (CV). The normality of data distribution was assessed using the Kolmogorov–Smirnov test (K-S), while homogeneity of variances between groups was verified using Levene's test. In cases where the data did not meet the assumptions of normal distribution, the nonparametric Mann–Whitney U test was applied (results are not shown, as all tests met the criteria for normality). Relationships between performances across disciplines were examined using the Pearson correlation coefficient, with statistical significance set at $p < 0.05$. Multivariate analysis (MANOVA) was conducted to assess the overall effect of group membership on the combination of performances across all running disciplines. For individual distances, univariate analysis of variance (ANOVA) was performed, with Tukey HSD post hoc test used to identify significant differences between student generations. Statistical significance was determined at $p < 0.05$*; $p < 0.01$**.

RESULTS

Descriptive statistics for the running events (100 m, 200 m, 400 m, and 800 m) provide insight into participants' baseline running abilities and variability within the sample (Table I). The average time for the 100 m sprint was 13.26 s (min = 10.90 s; max = 16.70 s). The range of 5.80 s and relatively low standard deviation (SD = 0.92 s; 95 % CI: 0.84 – 1.02) indicate relatively low dispersion in maximal sprinting speed. The coefficient of variation (CV = 6.94 %) further confirms moderate individual differences, with most participants performing close to the mean.

For the 200 m event, the mean time increased to 28.59 s (min = 22.90 s; max = 36.16 s), with a larger SD (2.41 s; 95% CI: 2.20–2.67) and higher CV (8.44%), reflecting greater heterogeneity. This is consistent with the greater demand to sustain high intensity over a longer distance. The 400 m showed further increases in variability (mean = 68.89 s; min = 54.73 s; max = 97.00 s; SD = 6.41 s; CV = 9.31 %), and the large range (42.27 s) indicates substantial individual differences. The highest relative variability was observed in the 800 m (mean = 2.71 min; min = 2.13 min; max = 3.50 min; SD = 0.32 min; CV = 11.87 %). Although absolute dispersion was moderate, the higher CV indicates more pronounced individual differences at longer distances. Kolmogorov–Smirnov tests ($p > 0.05$) showed no significant deviations from normality, supporting the use of parametric analyses. Levene's test confirmed homogeneity of variances across disciplines. Overall, variability increased with distance, suggesting greater inter-individual differences in longer events. These findings provide a basis for interpreting generational differences and correlations between sprint and middle-distance performances.

Table II presents descriptive statistics of running performance in the 100 m, 200 m, 400 m, and 800 m disciplines for 12 generations of participants. The analysis includes mean values and SD, allowing for the assessment of central tendency and variability within each group. In the 100 m discipline, average times ranged from 12.09 ± 0.60 s (Group 2) to 13.82 ± 1.06 s (Group 11). The best results were achieved by Group 2 and 3, with mean times below 13 s, indicating above-average sprinting abilities in these generations. In contrast, Groups 10 and 11 showed lower average performance and greater variability (SD between 0.73 and 1.18 s), which may be due to differences in training status, motivation, or a heterogeneous group composition in terms of previous sports experience.

For the 200 m event, the fastest average time was recorded by Group 2 (26.46 ± 2.97 s), while the slowest was Group 5 (29.38 ± 2.93 s). Standard deviations in this discipline were higher than in the 100 m, indicating greater within-group heterogeneity. This is expected, as the 200 m sprint combines speed and anaerobic endurance, so participants with similar sprinting speed may differ significantly in their ability to maintain pace in the second half of the race. Generation 5 stands out for high variability, suggesting substantial individual differences in sprint endurance within this generation.

Average times for the 400 m ranged from 65.38 ± 7.91 s (Group 3) to 71.01 ± 4.01 s (Group 4). Group 3 again demonstrated the best results, consistent with their performance in the 100 m and 200 m, indicating a generation with well-developed anaerobic capacity and an optimal balance of speed and endurance. The highest standard

Table I. Descriptive statistics of running disciplines (n=210).

Distance	Mean	Min.	Max.	Range	SD	CI ± 95 %	CV %	SE	K-S	Leven's test
100m (s)	13.26	10.90	16.70	5.80	0.92	0.84-1.02	6.94	0.06	0.124	0.144
200m (s)	28.59	22.90	36.16	13.26	2.41	2.20-2.67	8.44	0.17	0.186	0.585
400m (s)	68.89	54.73	97.00	42.27	6.41	5.84-7.10	9.31	0.45	0.153	0.271
800m (min)	2.71	2.13	3.50	1.37	0.32	0.29-0.36	11.87	0.02	0.262	0.112

Mean = average; Min. = minimum; Max. = maximum; Range = difference between max. and min.; SD = standard deviation; CI ± 95 % = 95 % confidence interval; CV % = coefficient of variation; SE = standard error; K-S = Kolmogorov-Smirnov test for normality; Levene's test = test for homogeneity of variance. Distances: 100 m, 200 m, 400 m (seconds) and 800 m (minutes).

Table II. Average values of running disciplines by groups.

Group	N	100m (s) Mean± SD	200m (s) Mean ± SD	400m (s) Mean±SD	800m (s) Mean± SD
1.	26	13.24 ± 0.66	28.70 ± 2.14	69.64 ± 4.98	2.62 ± 0.23
2.	19	12.09 ± 0.60	26.46 ± 2.97	70.86 ± 9.08	2.67 ± 0.33
3.	26	12.91 ± 0.83	28.10 ± 2.86	65.38 ± 7.91	2.55 ±0.25
4.	18	13.04 ± 0.62	28.85 ± 1.92	71.01 ± 4.01	2.76 ± 0.33
5.	13	12.93 ± 0.84	29.38 ± 2.93	68.12 ± 6.98	2.65 ± 0.36
6.	21	13.60 ± 0.85	29.30 ± 2.06	69.00 ± 5.50	2.73 ± 0.26
7.	16	13.32 ± 0.76	28.79 ± 2.02	69.34 ± 4.07	2.77 ± 0.31
8.	19	13.69 ± 1.18	28.67 ± 2.42	68.82 ± 7.53	2.70 ± 0.40
9.	14	13.53 ± 0.73	28.33 ± 2.26	68.41 ± 5.01	2.85 ± 0.37
10.	13	13.62 ± 1.14	28.71 ± 2.19	69.76 ± 6.52	2.82 ± 0.42
11.	12	13.82 ± 1.06	29.26 ± 2.60	70.77 ± 7.32	2.82 ± 0.29
12.	13	13.43 ± 0.64	28.89 ± 1.77	68.68 ± 5.36	2.79 ± 0.36

Values are presented as mean ± standard deviation (SD) for each running discipline by generation. N = number of participants in each group. Distances: 100 m, 200 m, 400 m, and 800 m, measured in seconds (s).

deviation was recorded in Group 2 (SD = 9.08 s), significantly higher than in other groups, reflecting pronounced differences in the ability to maintain high intensity throughout the race. This variability may result from uneven training status or different tactical approaches within the group.

For the 800 m, average times ranged from 2.55 ± 0.25 min (Group 3) to 2.85 ± 0.37 min (Group 9). Although the absolute range is greater than in sprint events, standard deviations remain relatively consistent (0.23 – 0.42 min), indicating lower within-group heterogeneity. This may be because the 800 m requires a combination of aerobic and anaerobic capacity, and participants from the same generation likely follow similar conditioning programs. The best performance by Group 3 confirms previous trends, highlighting consistently strong results for this generation across all disciplines. Overall, the analysis shows that Groups 2 and 3 were the most consistent and highest-performing in sprint disciplines (100 m and 200 m) as well as in the more demanding middle-distance events (400 m and 800 m). Low within-group variability in key disciplines may reflect a homogeneous level of training, favorable training conditions, or an optimal selection process. In contrast, some groups (e.g., 5, 8, 10, and 11) are characterized by greater dispersion of results, indicating a wide range of performance levels within the group. Sprint disciplines show greater variability between groups, which is expected given that short distances depend heavily on speed and neuromuscular abilities, which naturally vary among individuals. For middle-distance events (400 m and 800 m), differences between groups are smaller, suggesting that generations are more similar in aerobic–anaerobic capacities, likely due to similar long-term training programs. Overall, it is clear that Groups 2 and 3 lead in most disciplines, while increased variability in certain groups highlights the need for further analysis of factors contributing to heterogeneity and the potential adjustment of training to ensure consistent progress among all members.

Table III presents the inter-correlations between performances in the running disciplines among participants, with all correlations being statistically significant at $p < 0.01$. The results show that performances in sprint disciplines are strongly interrelated. The strongest correlation was observed between the 100 m and 200 m ($r = 0.799$, $p < 0.001$, $r^2 = 0.639$, large effect), indicating that participants who perform well in the shortest sprint generally also achieve better results in the 200 m. This high association confirms the key role of maximal speed in short sprints. The correlation between 100 m and 400 m was moderate ($r = 0.583$, $p < 0.001$, $r^2 = 0.340$, medium effect), while the correlation between 200 m and 400 m was stronger ($r = 0.686$, $p < 0.001$, $r^2 = 0.471$, large effect). This suggests that although speed is the primary factor in the 400 m, anaerobic endurance and the ability to maintain high intensity over a longer sprint distance also play a significant role.

Table III. Correlation between running (n=210).

Distance	r	P	r^2 (Cohen's effect size)
100m *vs.* 200m	0.799	< 0.001	0.639
100m *vs.* 400m	0.583	< 0.001	0.340
100m *vs.* 800m	0.542	< 0.001	0.294
200m *vs.* 400m	0.686	< 0.001	0.471
200m *vs.* 800m	0.527	< 0.001	0.278
400m *vs.* 800m	0.666	< 0.001	0.444

r= correlations; r^2 = proportion of variance explained, interpreted as Cohen's effect size. Small effect: r = 0.10; Medium effect: r = 0.30; Large effect: r = 0.50. All correlations are statistically significant at $p < 0.01$.

Performance in the 800 m showed moderate correlations with sprint disciplines: 100 m ($r = 0.542$, $p < 0.001$, $r^2 = 0.294$, medium effect) and 200 m ($r = 0.527$, $p < 0.001$, $r^2 = 0.278$, medium effect), while

Table IV. Multivariate tests of significance sigma-restricted parameterization effective hypothesis decomposition.

	Test	Value	F	Effect - df	Error - df	p	h^2
Intercept	Wilks' Lambda	0.005	10126.62	4.00	187.00	0.000*	0.995
Group	Wilks' Lambda	0.481	3.44	44.00	717.37	0.000*	0.519

Wilks' Lambda - was used to test multivariate significance. F-statistic; p - significance level; η^2 - Cohen's effect size; $p < 0.05$ indicates statistical significance, and * significance at $p < 0.05$.

the correlation with 400 m was stronger ($r = 0.666$, $p < 0.001$, $r^2 = 0.444$, large effect). These findings indicate that success in middle-distance events depends on a combination of speed and endurance. While performances in shorter sprints can partially predict success in the 800 m, physiological capacities required to sustain pace over the longer distance play a more critical role. Overall, the correlations highlight overlapping abilities between sprint and middle-distance disciplines. Speed dominates performance in shorter events (100 m and 200 m), whereas aerobic–anaerobic endurance becomes critical for the 400 m and 800 m. Cohen's r∑ values further confirm the effect sizes, suggesting that training programs should be specifically tailored to the demands of each distance, balancing speed and endurance components according to the targeted discipline.

Multivariate analysis (MANOVA) based on the data from Table IV shows the existence of statistically significant differences between groups when considering the combination of all dependent variables—times achieved in the 100 m, 200 m, 400 m, and 800 m events. The Wilks' Lambda value for the group effect was 0.481, with a corresponding F-test of 3.44, a highly significant p-value ($p < 0.001$), and a large effect size ($\eta^2 = 0.519$). These results indicate a clear and significant difference in overall running performance between groups, confirming that group membership significantly affects the combination of results across all disciplines. In other words, although individual events may show varying degrees of influence, the groups differ significantly in overall performance when considered together.

Analysis of individual events using univariate analysis of variance (Table V) shows that significant differences between generations are present only in the 100 m sprint, where $F = 4.767$ and $p < 0.001$, with a large effect size ($\eta^2 = 0.212$). This indicates that performance in the shortest distance is strongly associated with group membership, reflecting clear and systematic differences in speed and running ability between generations. In contrast, for longer events (200 m, 400 m, and 800 m), differences between groups were not statistically significant ($p > 0.05$), with small effect sizes ($\eta^2 = 0.082$ for 200 m, $\eta^2 = 0.066$ for 400 m, and $\eta^2 = 0.082$ for 800 m). Although some variation was observed (200 m: $F = 1.572$; 400 m: $F = 1.228$; 800 m: $F = 1.579$), these differences were not large enough to be considered reliable. This suggests that group membership has a significant impact on combined performance, but its individual effect is most pronounced in short sprint disciplines, particularly the 100 m. For longer distances, the effects decrease, indicating that physical and tactical differences between groups have a stronger impact on short sprints than on middle- and long-distance races.

Tukey HSD analysis for the 100 m sprint (Table V) shows that the second group (Mean = 12.09 s) differs significantly from most other generations, particularly compared to group 1 (Mean = 13.24 s, $p = 0.001$, $d = -1.81$), 6

Table V. Analysis of variance.

Distance	SS Effect	MS Effect	SS Error	MS Error	F	p	__	Tukey HSD test: 100 m	Cohen's D	200 m	Cohen' D
100 m (s)	36.95	3.36	137.41	0.70	4.767	0.000**	0.212	2. gr. *vs.*		2. gr. *vs.*	
								1. gr. = 0.001**	-1.81 - large	5.gr. = 0.024*	-0.99 - large
200 m (s)	97.64	8.88	1089.48	5.64	1.572	0.109	0.082	6. gr. = 0.000**	-2.03 - large	6.gr. = 0.018*	-1.12 - large
								7. gr. = 0.007**	-1.80 - large		
400 m (s)	548.44	49.86	7796.18	40.61	1.228	0.271	0.066	8. gr. = 0.000**	-1.71 - large		
								9. gr. = 0.001**	-2.19 - large		
800 m (s)	1.74	0.16	19.43	0.10	1.579	0.107	0.082	10. gr. = 0.000**	-1.77 - large		
								11. gr. = 0.000**	-2.15 - large		
								12. gr. = 0.003**	-2.17 - large		

SS - sum of squares; MS - mean square; F-statistic; p - significance level; η^2 - Cohen's effect size; Tukey HSD- post hoc comparisons between groups; Statistically significant differences are indicated as *$p < 0.05$ and **$p < 0.01$.; Cohen's D effect: small ≥ 0.2; medium ≥ 0.5; large ≥ 0.8.

(Mean = 13.60 s, p = 0.000, d = -2.03), 7 (Mean = 13.32 s, p = 0.007, d = -1.80), 8 (Mean = 13.69 s, p = 0.000, d = -1.71), 9 (Mean = 13.53 s, p = 0.001, d = -2.19), 10 (Mean = 13.62 s, p = 0.000, d = -1.77), 11 (Mean = 13.82 s, p = 0.000, d = -2.15), and 12 (Mean = 13.43 s, p = 0.003, d = -2.17). This clearly indicates that the second generation leads in sprint performance. No significant differences were found with generations 3 (Mean = 12.91 s, p = 0.611), 4 (Mean = 13.04 s, p = 0.224), and 5 (Mean = 12.93 s, p = 0.094), showing relatively consistent times among the middle generations.

Tukey analysis for the 200 m discipline shows that the second group (Mean = 26.46 s) differs significantly only from specific groups, particularly the fifth (Mean = 29.38 s, p = 0.024, d = -0.99) and sixth (Mean = 29.30 s, p = 0.018, d = -1.12) groups. Most other comparisons between generations were not statistically significant (p > 0.05), suggesting that sprint performance in the 200 m is relatively similar across generations. For the 400 m and 800 m events, average times ranged from 65.38 s (Group 3) to 71.01 s (Group 4) and from 2.55 min (Group 3) to 2.85 min (Group 9), respectively. Although absolute differences exist, Tukey HSD analysis confirms that these differences are not statistically significant (p > 0.05). Therefore, performance across generations in middle-distance events does not show significant differences. In summary, group or generational membership has a significant effect on combined performance, but the greatest effect is observed in the 100 m sprint. Longer events (200 m, 400 m, and 800 m) show lower heterogeneity between generations, suggesting that aerobic–anaerobic capacity and tactical consistency reduce differences. The second group consistently leads in sprint disciplines, while the middle group are relatively homogeneous.

DISCUSSION

Continuous monitoring of student athletic performance is essential for tailoring individualized training programs, optimizing curricula, and supporting holistic physical development. The primary aim of this study was to analyze interrelationships among sprint and middle-distance running disciplines across twelve generations of male students. The multivariate analysis of variance (MANOVA) revealed statistically significant differences among generations in overall performance across all measured disciplines (Wilks' Lambda = 0.481; F = 3.44; p < 0.001; η^2 = 0.519), indicating that generational membership significantly influences the combination of sprinting and middle-distance performance. This finding justifies the subsequent application of univariate ANOVAs to explore individual event differences (Table IV).

The univariate analyses showed that statistically significant generational differences were observed primarily in the 100 m sprint (F = 4.767; p < 0.001; η^2 = 0.212), with Group 2 outperforming all others (M = 12.09 s). In the 200 m sprint, only limited significant differences were found, where group 2 also showed the highest mean (M = 26.46 s) (Table V). Longer distances (400 m and 800 m) did not demonstrate statistically significant differences between generations (p > 0.05; η^2 = 0.066–0.082), suggesting that factors affecting sprint performance vary more between groups than those influencing middle-distance events. These findings may reflect differences in student selection, training experience, and age-related maturation, as older students typically exhibit improved sprint performance due to neuromuscular development and force generation capacity (Balsalobre-Fernández *et al.*, 2016). Moreover, Group 2 may have included a higher proportion of students with prior competitive experience or elite athletic background, consistent with findings emphasizing the impact of systematically guided training on performance outcomes (Barnes & Kilding, 2015).

Correlation analyses further support these interpretations. Strong positive correlations were observed between 100 m and 200 m performances (r = 0.799; r^2 = 0.639; p < 0.001), indicating that short-sprint capabilities are highly interdependent, reflecting maximal force production and neuromuscular efficiency (Jiménez-Reyes *et al.*, 2022; Lin *et al.*, 2023; Belechris *et al.*, 2025). Moderate correlations were identified between sprint and middle-distance events, such as 100 m – 800 m (r = 0.542; r∑ = 0.294) and 200 m – 800 m (r = 0.527; r^2 = 0.278), suggesting that while sprint speed contributes to middle-distance performance, endurance-related physiological factors increasingly modulate results over longer distances (Gupta *et al*., 2021; Campos *et al*., 2022; Miroshnichenko *et al.*, 2024). The relatively strong correlations between 200 m – 400 m (r = 0.686; r^2 = 0.471) and 400 m – 800 m (r = 0.666; r^2 = 0.444) reflect the transitional energy system demands between anaerobic and aerobic metabolism, emphasizing the integrative contribution of both speed and endurance capacities to performance success (Table III).

Performance in the 800 m event highlights its nature as a transitional discipline. Although aerobic metabolism predominates over its duration, sprint speed, acceleration ability, and anaerobic power significantly affect performance, particularly during the initial and final phases of the race (Morin *et al.*, 2011; Thompson, 2017). Consequently, the moderate yet significant correlations between the 800 m and shorter distances, especially 400 m, can be explained by overlapping pacing strategies and metabolic demands. This supports the notion that middle-distance performance among students is not solely an aerobic test but requires a combination of speed, anaerobic power, and neuromuscular efficiency (Sandford *et al*., 2019a; Belechris *et al*., 2025). Biomechanical determinants provide an additional explanatory framework. Maximum running speeds in 100 m and 200 m are achieved through high vertical ground reaction forces applied over very short contact times (Lin *et al*., 2023). Hence, the strong correlation between these disciplines aligns with the shared dependence on neuromuscular and mechanical efficiency. Conversely, the weakest correlation observed between 100 m and 800 m reflects the dominance of distinct energy systems and physiological capacities in these events. Variability among participants is further influenced by prior sport specialization, with students from team and individual sports exhibiting different representations of energy systems and mechanical strategies.

Generational comparisons also reveal differences in variability. Sprint disciplines (100 m, 200 m) demonstrated relative homogeneity, suggesting that baseline speed abilities may reach a genetically or developmentally determined ceiling within this population. Middle-distance events (400 m, 800 m) showed higher inter-individual variability, likely influenced by aerobic fitness, training history, motivation, and lifestyle factors (Nazihra *et al*, 2024). These findings underscore the influence of modern sedentary behaviors on prolonged-duration performance, highlighting the need for structured interventions targeting endurance development. From a practical standpoint, the observed interrelationships suggest that enhancing sprint capacity may positively transfer to middle-distance performance, particularly in students with foundational training levels. Incorporating maximal and explosive strength elements alongside sprint training can therefore optimize performance even in curricula emphasizing endurance. The consistency of these findings across multiple generations emphasizes the value of longitudinal monitoring in identifying trends, refining selection criteria, and individualizing training programs (Kozin *et al*., 2023; Rebbouj & Lotfi, 2024).

Finally, these results have broader implications beyond sport performance. Understanding generational differences and the interplay between speed and endurance contributes to optimizing physical education curricula, promoting health, and fostering the development of future sport educators and coaches. Continuous, analytically grounded evaluation provides a framework for evidence-based decision-making, ensuring that interventions are appropriately tailored to the physiological and biomechanical demands of each discipline.

In conclusion, generational differences in running performance are most pronounced in short sprints, with sprint ability partially predicting middle-distance outcomes. A multivariate analytical approach combining descriptive statistics, correlations, and variance analyses enables a comprehensive understanding of interrelationships in student running performance. These insights support targeted training, informed curriculum design, and individualized athlete development, bridging physiological mechanisms, biomechanical determinants, and practical applications in sport education.

Limitations of the Study

The study has several limitations, including the fact that the sample consisted exclusively of male students, which reduces the generalizability of the findings, as well as the possibility of minimal subjective error resulting from manual time measurement. Since the tests were conducted outdoors, the results may have been influenced by varying weather conditions, and the long-term longitudinal design may involve uncontrolled changes in the curriculum or equipment. Additionally, the analysis included only four running disciplines, without considering other relevant physical or biomechanical factors.

Directions for Future Research

Future research should therefore include female participants and a broader population, employ electronic systems for more accurate time measurement, and examine additional physical and biomechanical aspects such as strength, agility, and running technique. It would also be useful to monitor the impact of training processes and educational programs on student performance, as well as conduct long-term analyses of performance and training effects after graduation.

Practical Implications

In practical terms, the findings may contribute to optimizing training programs tailored to individual abilities, improving the physical education curriculum by emphasizing speed, endurance, and coordination, and continuously monitoring progress to identify students who require additional guidance. Moreover, the results may aid in selecting and specializing athletes based on their potential, while the application of standardized warm-up routines and rest intervals may help prevent injuries and increase the validity of performance outcomes.

CONCLUSION

The results of this study showed statistically significant differences in performance between student generations, confirming the first hypothesis regarding the existence of generational variations in running abilities within the examined population. Correlations between sprint and middle-distance performances were also statistically significant, supporting the second hypothesis on the interrelationship of athletic disciplines. Key conclusions are:

1. Homogeneity of middle-distance performance: Unlike sprint disciplines (100 m and 200 m), performances in the 400 m and 800 m events were relatively similar across generations within this specific student population. Small effect sizes (η^2 = 0.07–0.08) indicate that generational differences in these distances are limited.
2. Impact of within-group variability: Greater dispersion of results within individual groups suggests that differences in conditioning, physical predispositions, and tactical execution are more important than generational differences.
3. Practical interpretation: Although mean times show some variation, generations cannot be considered statistically different in middle-distance performance. Analyses should therefore focus on within-group trends and individual differences rather than generalizing the superiority of any generation.

In conclusion, generational differences in performance are most pronounced in sprint disciplines, while middle-distance performance appears relatively homogeneous among students. These findings are specific to the studied population and cannot be directly generalized to all athletes. Future research should include diverse populations and examine the influence of factors such as previous sports experience, training level, and physical predispositions.

Conflict of interest. The authors declare no conflict of interest.

PAVLOVIC, R.; MIHAJLOVIC, I.; RADULOVIC, N.; BADAU, D.; BADICU, G. & KOZIN, S. Rendimiento en carrera de estudiantes de educación física y deportes: Un análisis descriptivo longitudinal y multivariado. *Int. J. Morphol., 44(3)*:924-933, 2026.

RESUMEN: El seguimiento del rendimiento en carrera proporciona información importante sobre el desarrollo fisiológico, la eficacia del entrenamiento y las diferencias individuales en velocidad y resistencia, ya que las pruebas de velocidad y media distancia requieren diferentes contribuciones de las capacidades anaeróbica y aeróbica. El objetivo de este estudio fue analizar las diferencias generacionales y las interrelaciones en el rendimiento en pruebas de corta y media distancia entre doce generaciones (grupos) de estudiantes. El estudio longitudinal incluyó a 210 estudiantes de tercer año de la Facultad de Educación Física y Deporte durante un período de 12 años, y el rendimiento se evaluó en las pruebas de 100 m, 200 m, 400 m y 800 m bajo condiciones estandarizadas. El análisis estadístico incluyó estadística descriptiva, pruebas de normalidad y homogeneidad, coeficientes de correlación de Pearson, MANOVA y ANOVA univariado con pruebas post hoc HSD de Tukey. El análisis de MANOVA reveló diferencias estadísticamente significativas entre generaciones en el rendimiento general (Lambda de Wilks = 0,481; F = 3,44; p < 0,001; η^2 = 0,519), mientras que el ANOVA univariado identificó diferencias significativas solo en la prueba de 100 m (F = 4,767; p < 0,001; η^2 = 0,212). Todas las pruebas mostraron una correlación positiva y estadísticamente significativa, observándose la correlación más fuerte entre los 100 m y los 200 m (r = 0,799; p < 0,001), y correlaciones moderadas entre los 100 m y los 800 m (r = 0,542), los 200 m y los 400 m (r = 0,686), y los 400 m y los 800 m (r = 0,666) (todas p < 0,001). El rendimiento en media distancia mostró una homogeneidad relativa entre generaciones, mientras que el rendimiento en velocidad demostró una mayor variabilidad, lo que indica que las diferencias generacionales son más pronunciadas en las pruebas de velocidad corta. El rendimiento en velocidad predice parcialmente los resultados de media distancia, confirmando la interacción entre la velocidad y la resistencia y subrayando la importancia del seguimiento continuo del rendimiento y la adaptación del entrenamiento a las exigencias específicas de cada disciplina.

PALABRAS CLAVE: Atletismo; Media distancia; Rendimiento estudiantil; Análisis multivariante.

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