

Clustering undergraduate students enrolled in physical education majors in Romania and Ukraine based on their physical fitness levels

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Abstract

Introduction: The World Health Organization (WHO) reports that nearly one third of the world's adults (31%) are physically inactive. This study explored gender differences in physical fitness among undergraduate students majoring in physical education. **Objective:** The main goal of this research was to analyze and compare physical fitness indicators between male and female higher education students. Specifically, we aimed to identify clusters of students based on their physical fitness profiles and understand the implications of these clusters on their overall health and fitness. **Methods:** A total of 324 students from Romania and Ukraine participated in the study. The Romanian students were enrolled at the Faculty of Physical Education and Sport, Babeș-Bolyai University, and the Ukrainian students were enrolled at the National University of Ukraine on Physical Education and Sport. A combination of physical fitness tests, including the Three Minute Step Test, Sit-up Test, Push-up Test, and Standing Long Jump Test, Plate tapping Test were used to assess various fitness parameters. Cluster analysis, specifically k-means clustering, was used to categorize students into distinct groups based on their fitness profiles. The Davies-Bouldin index was computed to evaluate the robustness of the cluster separation. Correlation analysis was performed to examine the relationships between different physical development and fitness indicators. **Results:** The analysis identified significant gender differences in physical fitness. Male students were divided into two clusters: Cluster 1 demonstrated superior cardiorespiratory endurance, muscle endurance, and strength, while Cluster 3 exhibited higher body weight-to-length ratios and better coordination and speed of upper limb movements. Female students, categorized in Cluster 2, showed superior coordination and speed of upper limb movements, but lower strength and endurance compared to males. The Davies-Bouldin index of 0.017 indicates strong separation between clusters. **Conclusions:** The present study highlights the critical importance of promoting physical fitness among higher education students. The findings suggest that higher body weight relative to height can negatively impact certain fitness aspects. Tailored fitness programs addressing specific gender and individual needs are essential. Continued research is necessary to further understand the factors influencing physical fitness and to develop effective strategies for improvement, ensuring students are well-prepared for both professional challenges and healthy, active lives.

Keywords: cardiorespiratory fitness, muscle endurance, coordination, speed, gender differences.

Introduction

Achieving a sufficient level of physical development and fitness among higher education students is paramount, as it not only facilitates the effective acquisition of theoretical knowledge and practical skills in their chosen field, but also enables active participation in public life. Moreover, it fosters adaptability to contemporary challenges and sustains the vitality, productivity, and mobility of young professionals (Antipova et al., 2020; Nesen & Klymenchenko, 2020). A strong physical fitness status can open the way for the desired career path. Students whose body mass index (BMI) values remain stable or decline over the course of college life are more likely to secure a satisfying career compared to those whose BMI values increase (Tang et al., 2024).

A comprehensive literature review reveals one major concern among scientists: the declining physical fitness of students enrolled in higher education institutions, alongside discrepancies between body weight and length (Andrieieva et al., 2023; Nesen & Klymenchenko, 2020; Petrytsia, 2018; Sydorova & Gorina, 2020). This trend is indicative of a progressive deterioration in health, evidenced by an increased proportion of students

classified under special medical groups and a surge in the incidence of morbidity among young individuals. These developments occur in conjunction with a reduction in physical activity levels and a lack of conscientiousness regarding personal health management (Byshevets et al., 2023; Pelekh & Grigus, 2016). Consequently, experts have observed a notable decline in physical fitness indicators among a significant portion of higher education students (Nesen & Klymenchenko, 2020). This trend has necessitated multiple revisions of physical fitness standards, leading to a relaxation of requirements across various educational institutions and the discontinuation of certain tests.

Some research has demonstrated that students' physical fitness levels tend to decline starting from their second year of study (Griban et al., 2020; Hakman et al., 2020). Furthermore, studies indicate that, in general, male individuals tend to outperform their female counterparts in terms of physical fitness (Kyrychenko et al., 2023a).

The analysis of scientific, methodological, and specialized literature underscores a concerning trend: contemporary students enrolled in higher education institutions exhibit diminished levels of physical fitness. Moreover, there is a discernible negative trajectory indicating a decline in physical fitness throughout the duration of their higher education studies (Gres & Ostroglyad, 2020; Korobeinikova et al., 2021; Syomova, 2018; Tamozhanska et al., 2018). Currently, various estimates suggest that between 49.3 to 75.1 percent of higher education students report reduced levels of physical fitness (Petrytsia, 2018; Sydorova & Gorina, 2020). This phenomenon can be attributed to the transition into an information-driven and subsequently digital society, wherein students increasingly allocate their time towards studying, communication, and entertainment through information and communication technologies (ICT). Consequently, this shift has drastically curtailed their engagement in physical activity (Asauliuk & Kashuba, 2021; Mayevska et al., 2014). Unfortunately, this trend has also affected students enrolled in physical education majors.

The aim of the present study was to explore gender differences in physical fitness among undergraduate students majoring in physical education. The main goal of this research was to analyze and compare physical fitness indicators between male and female Romanian and Ukrainian students. Specifically, we aimed to identify clusters of students based on their physical fitness profiles and understand the implications of these clusters on their overall health and fitness.

Methods

Participants

Guided by the principles of biomedical ethics and based on informed consent, measurements were performed on 324 undergraduate students enrolled in a physical education major from the Faculty of Physical Education and Sports, Babeș-Bolyai University, Romania, and from the National University of Ukraine on Physical Education and Sport, Ukraine.

The sample was randomly selected, with the primary criteria for participation in the measurements being the absence of somatic diseases that might hinder motor tests and voluntary participation in the study.

The average age of the participants was 20.95 ± 2.68 years. The gender distribution comprised 31% of female students (99 individuals) and 69% male students (225 individuals). In 2022, 201 students participated in the research. In 2023, 123 students participated in the study.

Procedure

The physical development and fitness of students were comprehensively assessed through the following measurements: body mass index (BMI, kg/m^2), VO_2max (Three Minute Step Test, ml/kg/min), speed and coordination capabilities of the upper extremities (Plate tapping test, sec), abdominal muscle strength (Sit up test, max reps in 30 sec), strength and endurance of the upper body muscles (Push-ups, max reps), and explosive power of the lower extremities (Standing long jump test, cm).

Measurements were conducted in Cluj-Napoca, Romania, in April of both 2022 and 2023, as well as in Kyiv, Ukraine, in 2022. Before each measurement, participants received a briefing session and participated in a preliminary warm-up routine.

Statistical Analysis

The statistical analysis was conducted using the k-means algorithm, a machine learning technique, implemented in STATISTICA Data Mining. This method automatically groups data into clusters of similar objects. The algorithm determines cluster centers and iteratively assigns data points to the nearest center, effectively dividing the data into k-clusters.

Cross-validation was employed to automatically select the optimal number of clusters (k). This approach ensures a more robust estimate of clustering quality by assessing multiple samples, enhancing the reliability of the results.

To assess the quality of clustering, a method was employed where the data was partitioned into 10 subsets. Nine subsets were utilized for training the model, which involved identifying cluster centers, while one subset was reserved for evaluation. This process was repeated 10 times, ensuring each subset was used once for evaluation (Lazko et al., 2021; Leis et al., 2020).

The entire dataset, consisting of 324 objects, was utilized for both training and evaluating the model through cross-validation. During the model training stage, the average intra-cluster distance (internal variance) was found to be 0.313 (Byshevets et al., 2019a; Byshevets et al., 2019).

The quality of clustering was assessed using the Davies-Bouldin Index, which was calculated using the following formula:

$$DB = \frac{1}{k} \sum_{i=1}^k \max_{j \neq i} \left(\frac{S_i + S_j}{d(c_i, c_j)} \right), \quad (1)$$

where k – number of clusters;

S_i – is the average distance from object i to the centroid c_i ;

$d(c_i, c_j)$ – is the distance between the centroids of clusters i and j , which was calculated as the Euclidean distance by the formula:

$$d(c_i, c_j) = \sqrt{\sum_{k=1}^n (c_{i,k} - c_{j,k})^2}, \quad (2)$$

where n – number of indicators studied;

$c_{i,k}$, $c_{j,k}$ – k -th centroid index c_i and c_j .

The hypothesis test regarding the conformity of empirical data to the normal distribution law, conducted through the Kolmogorov-Smirnov criterion, revealed that students' distribution did not adhere to normality across the examined indicators. Consequently, the non-parametric Spearman's coefficient (ρ) was employed to evaluate the magnitude and direction of the relationship between physical development and fitness indicators among representatives of distinct clusters.

It's important to note that in interpreting the coefficient, consideration was given to the statistical significance of Spearman's coefficient, indicating whether the observed relationship could confidently be deemed non-random. Throughout the study, a significance level of 0.05 ($p < 0.05$) was employed.

Statistical analyses were conducted utilizing STATISTICA 10.0 (StatSoft).

Following a series of studies aimed at uncovering trends in the physical development and motor skills of students, incomplete data were obtained. Given that the missing data follow the Missing Completely at Random (MCAR) pattern, suggesting their random occurrence (e.g., absence due to illness or other reasons), we initially employed the method of outlier exclusion. This approach was utilized to assess the normality of data distribution and conduct a comparative analysis, as advocated by Papageorgiou et al. (2018) and Jäger et al. (2021). Notably, the proportion of outliers in the dataset varied from 2 to 4.5 percent for male students, and 2.4 to 11.0 percent for female students.

Results

The utilization of cluster analysis yielded unexpected findings. Despite the acknowledged disparities in the studied indicators between male and female students ($\chi^2=324.0$; $p<0.05$), the student sample was categorized into three clusters. Cluster 1 comprised 134 male students, Cluster 2 encompassed 99 female students, and Cluster 3 included the remaining 91 male students.

Observing the results of the Plate tapping test, which evaluates coordination and speed of upper limb movements, depicted in the figure, it's evident that females outperformed males (Fig. 1).

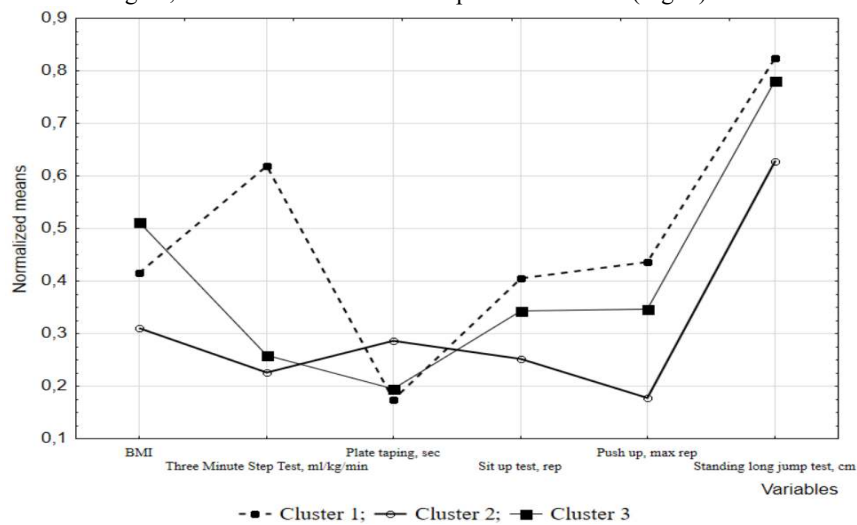


Fig. 1. Graph of means for continuous variables for the different clusters

Meanwhile, in contrast to females, males from both clusters exhibited higher scores across other tests and physical development indicators. Notably, males from Cluster 1 demonstrated superior performance in the Three Minute Step Test (ml/kg/min), indicating elevated cardiorespiratory endurance compared to males from Cluster 3 and females. Additionally, Cluster 1 outperformed representatives of other clusters in the Sit-up test

(repetitions), assessing muscle endurance and abdominal strength, the Push-up test (maximum repetitions), evaluating strength abilities, and the Standing long jump test, demonstrating their speed and strength capabilities. The centroids for k-means clustering are presented in Table 1.

Table 1

Centroids for k-means clustering (by indicators of physical development and physical fitness of students)

Cluster	Gender	BMI [kg/m ²]	Three Minute Step Test [ml/kg/min]	Plate taping [sec]	Sit up test [rep]	Push up [max rep]	Standing long jump test [cm]
1 (n=134)	Males	23.29	59.93	8.76	25.75	39.34	233.69
2 (n=99)	Females	21.63	40.28	10.08	21.28	16.62	178.70
3 (n=91)	Males	24.78	41.98	9	23.93	31.45	221.75

Subsequent investigations have revealed statistically significant differences among all indicators of students assigned to different clusters (Table 2).

Table 2

ANOVA for continuous variables (by indicators of physical development and physical fitness of students)

Indicators	Between SS	df	Within SS	df	F	p value
BMI	471.6	2	2498.5	321	30.297	<0.05
Three Minute Step Test [ml/kg/min]	28025.8	2	14370.3	321	313.017	<0.05
Plate taping [sec]	105.1	2	865.9	321	19.479	<0.05
Sit up test [rep]	1138.5	2	5736.6	321	31.854	<0.05
Push up [max rep]	29601.7	2	48733.4	321	97.491	<0.05
Standing long jump test [cm]	180755.1	2	181737.0	321	159.633	<0.05

Notes: Between SS (Sum of Squares) reflects the variability between clusters and illustrates the extent to which students' scores in different groups diverge from each other (with a degree of freedom (df) equal to k-1, where k is the number of groups). SS represents the variability within clusters and indicates the variance in students' performance within a single cluster (with a degree of freedom (df) equal to n-k, where n is the total amount of data and k is the number of groups). The F-statistic is utilized to assess the statistical significance of the difference between groups, with significance typically set at $p < 0.05$.

Thus, Cluster 1 comprised males with a lower body weight-to-length ratio, possessing elevated cardiorespiratory endurance compared to Cluster 3 and females, alongside the lowest coordination and speed of upper limb movement, yet demonstrating superior muscle endurance, press strength, and power and speed-power abilities. On the other hand, females in Cluster 2 exhibited a lower body weight-to-length ratio than males, showcasing superior coordination and speed of upper limb movements compared to males, yet displaying lower muscle endurance, abdominal strength, and strength and speed-power abilities in comparison to both clusters of males. As for participants in Cluster 3, they demonstrated the highest body weight-to-length ratio among the clusters. While their muscle endurance and abdominal strength, as well as power and speed-power abilities, surpassed those of females, they fall short compared to males in Cluster 1. However, their coordination and speed of upper limbs exceeded that of males in Cluster 1.

The computed Davies-Bouldin index, nearing zero at 0.017, suggests robust separation between clusters, with each cluster effectively represented by its mean value. Consequently, unlike females, males were categorized into two distinct clusters based on physical development and fitness. Evidently, males' higher body weight relative to length contributes to a decline in their overall physical fitness, albeit with exceptions noted in coordination and speed of upper limb movements.

Correlation analysis of physical development and fitness indicators among students unveiled notable discrepancies between representatives of Cluster 1 and Cluster 3 (refer to Table 3 and Table 4).

Table 3

Correlation analysis of indicators of physical fitness of students of Cluster 1

Indicators	BMI	Three Minute Step Test [ml/kg/min]	Plate taping [sec]	Sit up test [rep]	Push up [max rep]	Standing long jump test [cm]
BMI	1.000	0.070	-0.150	-0.002	0.125	-0.185
Three Minute Step Test [ml/kg/min]		1.000	0.210*	-0.003	0.009	-0.055
Plate taping [sec]			1.000	-0.023	-0.126	-0.002
Sit up test [rep]				1.000	0.206*	0.064
Push up [max rep]					1.000	0.242*
Standing long jump test [cm]						1.000

Note: * with proven statistical significance of the correlation ($p < 0.05$)

Cluster 1 students exhibited statistically significant positive correlations between cardiorespiratory endurance and coordination/speed of upper limb movements, strength abilities and muscle endurance/abdominal strength, as well as power/speed and strength abilities. Conversely, Cluster 3 students demonstrated inverse correlations between body weight-to-length ratio and muscle endurance/abdominal strength, as well as between cardiorespiratory endurance and strength abilities. Analogous to Cluster 1 students, the strength abilities of Cluster 3 students escalated alongside their muscular endurance and abdominal strength.

Table 4

Correlation analysis of indicators of physical fitness of students of Cluster 3

Indicators	BMI	Three Minute Step Test [ml/kg/min]	Plate taping [sec]	Sit up test [rep]	Push up [max rep]	Standing long jump test [cm]
BMI	1.000	0.157	-0.006	-0.249*	-0.160	-0.075
Three Minute Step Test [ml/kg/min]		1.000	-0.042	-0.195	-0.207*	0.029
Plate taping [sec]			1.000	-0.053	-0.076	-0.177
Sit up test [rep]				1.000	0.230*	0.066
Push up [max rep]					1.000	0.145
Standing long jump test [cm]						1.000

Note: * with proven statistical significance of the correlation ($p < 0.05$)

Hence, among students, an increase in the body weight-to-length ratio appears to impede the enhancement of muscle endurance and abdominal strength. Moreover, the inverse correlation between cardiorespiratory endurance and strength abilities could stem from several factors. Firstly, the tests assessing these motor abilities engage different types of muscle fibers: the push-up test predominantly activates fast-twitch muscle fibers (type II), which are glycolytic and prone to quick fatigue, whereas the three-minute step test primarily involves slow-twitch muscle fibers (type I), which utilize fat oxidation and demonstrate greater endurance. Secondly, this outcome might be attributed to differences in energy metabolism. Push-ups rely on anaerobic metabolism, which is less efficient and results in faster depletion of energy reserves, whereas the three-minute step test utilizes aerobic metabolism, known for its economy and prolonged activity support. Nevertheless, an inverse correlation does not establish a causal relationship between indicators. Consequently, further research is warranted to elucidate the underlying reasons for this relationship.

Table 5

Correlation analysis of indicators of physical fitness of students of Cluster 2

Indicators	BMI	Three Minute Step Test [ml/kg/min]	Plate taping [sec]	Sit up test [rep]	Push up [max rep]	Standing long jump test [cm]
BMI	1.000	-0.035	-0.103	0.103	0.050	-0.071
Three Minute Step Test [ml/kg/min]		1.000	0.291*	-0.094	0.060	-0.070
Plate taping [sec]			1.000	-0.362*	-0.218*	-0.400*
Sit up test [rep]				1.000	0.459*	0.273*
Push up [max rep]					1.000	0.303*
Standing long jump test [cm]						1.000

Note: * with proven statistical significance of the correlation ($p < 0.05$)

Moreover, a statistically significant ($p < 0.05$) correlation between cardiorespiratory endurance and coordination and speed of upper limb movements was established. Conversely, coordination and speed of upper limb movements exhibited an inverse relationship with muscular endurance and press strength, power, and speed-power abilities. These findings, akin to those observed in Cluster 3 students, underscore the necessity for further research aimed to examine the influence of various factors on strength abilities among female students (Table 5).

Discussion

The exploration of physical development characteristics and physical fitness among diverse socioeconomic groups, influenced by various physical activities, remains a paramount focus within research (Barkley et al., 2021; Chakhvadze et al., 2017; Elshaer et al., 2022; Hafsteinsson Östenberg et al., 2022; Nassif et al., 2012; Sang & Wang, 2022). Among these groups, undergraduate students stand out as a subject of significant interest for the scientific community (Boros-Balint et al., 2015; Deak et al., 2014; Hu et al. 2022; Kaj et al., 2015; Pribis et al., 2010). Notably, considerable emphasis has been placed on evaluating the physical fitness of students majoring in physical education (Bonilla et al., 2023; Gres & Ostroglyad, 2020; Kashuba et al., 2019; Kyrychenko et al., 2023). Published studies consistently highlight that, despite the escalating demands for

physical fitness among modern students, their actual fitness levels remain low (Antipova et al., 2020; Griban et al., 2020; Kyrychenko et al., 2023; Nesen & Klymenchenko, 2020; Tamozhanska et al., 2018).

Our study reveals several important insights regarding the physical fitness of the physical education students, focusing on gender differences and the clustering of students based on physical fitness attributes.

The finding that male students have higher overall physical fitness levels compared to female students ($p < 0.05$) is consistent with existing literature that highlights physiological differences, such as higher muscle mass and testosterone levels in males, which contribute to greater strength and endurance. However, female students outperformed males in the Modified Sit-and-reach test and Plate tapping test, indicating superior flexibility and coordination in these areas. This suggests that while males may generally excel in strength and endurance, females have advantages in specific fitness components. Despite this, we observed that not all male students have the same level of physical fitness. The cluster analysis helped understanding deeper variations among students regarding their physical fitness. Students that have been attributed to Cluster 1 (male students) have a lower body weight-to-length ratio, higher cardiorespiratory endurance, superior muscle endurance, abdominal strength, and speed-power abilities, but lower coordination and speed of upper limb movements. Females that composed Cluster 2 exhibit a lower body weight-to-length ratio than males, superior coordination, and speed of upper limb movements, but lower muscle endurance, abdominal strength, and speed-power abilities compared to males in both clusters. Individuals of Cluster 3 (male students) had the highest body weight-to-length ratio, better muscle endurance and abdominal strength compared to females, but lower than males from Cluster 1. Their coordination and speed of upper limb movements exceed those of Cluster 1. The Davies-Bouldin index of 0.017 indicates a strong separation between clusters, validating the distinct physical fitness profiles identified.

The correlation analysis uncovers significant relationships between various physical fitness components. Positive correlations exist between cardiorespiratory endurance and coordination/speed of upper limb movements, strength abilities and muscle endurance/abdominal strength, as well as power/speed and strength abilities.

Inverse correlations are observed between body weight-to-length ratio and muscle endurance/abdominal strength, and between cardiorespiratory endurance and strength abilities, highlight the potential negative impact of higher body weight-to-length ratios on muscle endurance and abdominal strength.

The differing muscle fiber types and energy metabolism involved in various tests (anaerobic for push-ups and aerobic for the three-minute step test) may explain the inverse correlation between cardiorespiratory endurance and strength abilities.

Conclusions

The findings of this study underscore the critical importance of fostering physical development and fitness among higher education students, especially those majoring in physical education. The data reveal a concerning trend of declining physical fitness levels among students, influenced by reduced physical activity and increased engagement with digital technologies. This decline is evident across various fitness indicators and highlights the necessity for targeted interventions to promote physical health.

Cluster analysis provided insightful distinctions among students, demonstrating significant gender differences in physical fitness and development. Notably, male students were divided into two clusters. Cluster 1 showed superior cardiorespiratory endurance and muscle strength, whereas Cluster 3 exhibited higher body weight-to-length ratios and better coordination and speed of upper limb movements. Female students, represented in Cluster 2, excelled in coordination and speed, but lagged in other strength and endurance measures compared to their male counterparts.

These disparities suggest that tailored fitness programs are essential to address specific needs based on gender and individual fitness profiles. The study highlights that higher body weight relative to height can impede certain fitness aspects, indicating the importance of maintaining a balanced physical development approach.

Furthermore, the observed correlations between different physical fitness indicators point to the complex interplay of various physiological factors. For instance, the inverse relationship between cardiorespiratory endurance and strength abilities suggests the need for a balanced approach in training programs to enhance overall fitness.

In conclusion, enhancing physical fitness among higher education students is vital not only for their academic and professional success, but also for their long-term health and well-being. Institutions should prioritize comprehensive fitness programs that cater to the diverse needs of students, promoting regular physical activity and healthy lifestyle choices.

Continued research is necessary to further understand the factors influencing physical fitness and to develop effective strategies for improvement. This study provides a foundation for future investigations aimed at optimizing physical education curricula and to ensure that graduates are well-prepared for both professional challenges and active, healthy lives.

Conflicts of interest. There is no conflict of interest to declare.

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