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Original article

Could Muscle Power and Muscle Endurance Influence Fire Emergency Response Movement Time in Young Adults?

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Abstract

This research sought to determine whether there was a direct relationship between muscle power, muscle endurance and emergency response times among young adults. While performance capability remains an essential component for emergency teams, this study showed how some physical fitness factors might alter initial emergency response time and lessen the effects of the disaster. Engagement in preparedness exercises, particularly those emphasizing physical activity, offers advantageous health outcomes and enhances disaster response efficacy. These improvements in readiness directly impact the overall outcomes of such disasters. The sample consisted of 21 students, comprising both male and female participants of the same age. Following the American College of Sports Medicine's (ACSM) Exercise Preparticipation Health Screening Questionnaire for Exercise Professionals, the participants were separated into two groups: the physically active group and the physically inactive group. The study's main objective was to determine whether muscle power and muscle endurance of the participants could influence their fire emergency response movement time to a safe location. Additionally, the study sought to find out whether physically active participants responded more quickly than physically inactive ones. The findings of this study indicate a relationship between emergency response time and measurements of muscle endurance and muscle power. Participants who were physically active had shorter movement time to safe location ($p = 0.023$), performed better on the standing broad jump test ($p = 0.001$), and muscle endurance test ($p = 0.004$). Although performance ability is a key component for emergency teams, this study demonstrated how some factors of physical fitness can affect initial emergency response time and help mitigate the effects of the disaster in young adults.

Keywords: Emergency Response, Health and safety, Physical fitness, Disaster preparedness, Fire Emergency, Evacuation

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Introduction

The initial moments of an emergency are pivotal for initiating actions that can enhance an individual's response to hazardous situations (Baldwin, 1994). Research indicates that emergency response teams are tasked with mitigating the impact of disasters. However, individuals in perilous situations can still preserve their own lives by taking swift action before aid arrives (Subramaniam, Ali, & Shamsudin, 2012). Recent research have shown that some physical fitness factors could influence faster emergency response in university students (Bajić, Veljović, & Bulajić, 2023).

There are three general ways to survive a fire: trying to put out the flames, taking cover and waiting for help, and evacuation (Tong and Canter, 1985). In this paper, we will assess the evacuation via the measurement of the required evacuation time in a controlled environment. For this study, the controlled environment will represent the already established evacuation route to the predetermined safe location, which is 30 meters outside of the building.

There are some factors that influence how people behave during a fire - the availability of fire safety measures (e.g. fire extinguishers), accessible escape routes, and assistance of professional emergency service. This research focuses primarily on behavior of the young adults in the case of a fire emergency in the form of evacuation time from the site in a controlled manner. Additionally, the research attempted to simulate the actual behavior of an untrained young adults that have never participated in organized evacuation drills.

Strength, endurance, and cardiorespiratory fitness are paramount physical prerequisites for optimal occupational performance (MacDonald, Pope, & Orr, 2016). Better performances in the field of physical fitness can hasten the process of minimizing the effects of disasters, such as lowering the risk of injury and loss of life (Maupin et al., 2018).

The relationship between occupants' emergency tasks and fitness level is clear, and numerous studies have been conducted and found to be reliable regarding the high level of strength and aerobic performance required by specialist police jobs like carrying loads, performing repetitive lifts, and performing a variety of carrying tasks (Robinson et al., 2018). Despite the fact that our study does not specifically address tactical people, various studies suggest that the general community could also gain from having high levels of physical fitness, which is directly associated to faster response times to disasters.

The study's main objective was to determine whether muscle power and muscle endurance of the participants could influence their fire emergency response movement time to a safe location. Additionally, it was hypothesized that the physically active participants will respond more quickly to fire emergency scenario than physically inactive ones.

Methods

Experimental approach to the problem

The objective of the present study is to investigate the potential impact of physical fitness on young adults aged 20 to 30, who were selected randomly for participation. The emergency fire case scenario assumes that the selected participants are attending lectures at the university building during a fire event. The goal is to determine whether participants who were physically active throughout the testing period differed from those who were not in terms of the amount of time they needed to respond to a safe place. Effects of a few fitness factors such as muscular power and muscle endurance were examined and their impacts on emergency response time in the case of fire emergency were compared. The intention was to categorize participants into two groups based on the information obtained from the pre-participation health screening questionnaire. It was hypothesized that significant differences in response times would be observed between the two groups.

Participants

The sample comprised 21 students, consisting of both male and female individuals of the same age, who volunteered for participation in the study. A pre-participation screening questionnaire was prepared by the researchers and used as a data collection form (American College of Sports Medicine, 2020). Following the American College of Sports Medicine's (ACSM) Exercise Preparticipation Health Screening Questionnaire for Exercise Professionals (American College of Sports Medicine, 2020), the participants were separated into two groups: the physically active group and the physically inactive group. The physically active group consisted of 10 students (mean Body Mass Index [BMI] = 25.04 ± 3.63 kg/m^2; mean percentage body fat [BF%] = 13.33 ± 5.81), while physically inactive group consisted of 11 students (mean Body Mass Index [BMI] = 25.02 ± 5.62 kg/m^2; mean percentage body fat [BF%] = 23.81 ± 7.96).

The study's main objective was to find out whether physically active participants responded more quickly than physically inactive ones. The initial session of the survey, focusing on physical fitness assessment, was conducted over a two-hour period on a single day. The subsequent session, dedicated to measuring fire emergency reaction time, extended for three hours, and was conducted seven days later. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Faculty of Technical Sciences, University of Novi Sad (protocol code 01-1626/3, 2023).

Measurements and Procedures

The pre-exercise evaluation included measurement of solely the resting blood pressure (BP). The *Procedures for Assessment of Resting Blood Pressure* recommended in the *ACSM Guidelines for Exercise Testing and Prescription* were used, as precise and proven methods for monitoring blood pressure are essential for accuracy (Gary et al., 2022). The results were successful as all the subjects had normal blood pressure according to the *Classification and management of blood pressure for adults*, and we could proceed with the testing.

Lower body power

Power, i.e. the capacity or rate at which a subject can execute work, is one of the skill-related physical fitness factors (Gary, 2022). In this study, the standing long jump, commonly known as the broad jump, was utilized to evaluate explosive leg power, a metric often employed to gauge overall muscle power. Participants were directed to position themselves with their feet slightly apart behind a line marked on the ground. They were then instructed to propel their bodies forward by swinging both arms, executing a two-foot takeoff and landing. The objective was for participants to land on both feet without falling backward while jumping as far as possible. Subsequently, following the completion of the test, the distance between the takeoff line and the closest point of contact of the subject's heels was measured (Wood, 2008). The longest distance jump was noted as the better of two tries.

Muscular endurance

Muscular endurance refers to the ability of a muscle group to sustain repetitive contractions over a period until muscular fatigue is reached (Gary et al., 2022). In this research, muscle endurance was assessed using a simple field test where participants performed the maximum number of push-ups they could execute without interruption (Canadian Society for Exercise Physiology, 2004). This method is employed to evaluate upper-body muscle endurance. Male participants in the test were directed to assume the standard "down" position (hands under the shoulders, back straight, head up, using toes as the pivot point), while female participants were instructed to start in the modified "knee push-up" position (Čvorović et al., 2021). For this study, yoga block was placed underneath the participant's chest and served as a measure of required push up depth. The maximal number of push-ups performed without rest was noted as the final score. The test was stopped when subject could not maintain appropriate technique and strained forcibly within two repetitions.

Emergency response

In this study, the term "emergency response test" pertains to the participant's ability to react to an emergency scenario, specifically measured by the time taken to reach a designated safe location. The test was conducted in the classroom that the selected participants frequented the most. Based on how they responded to a made-up emergency, subjects' performances and the actual times they needed to reach a safe area were evaluated. The time it took the subject to leave the building and reach the safe place was a measure of the initial emergency response. It was established how long it took for the subject to get to the safe area that had been previously selected by the building's fire protection plan (Faculty of Technical Sciences, 2022). Participants were acquainted with the procedure and the safest route which could take them to the safe location outside of the building.

Participants were situated in a classroom located on the elevated ground floor. As per the fire protection protocol, participants were required to exit through the main entrance door, descend 13 stairs to reach the exterior of the building, and subsequently proceed to run or walk the remaining distance from the starting point to the designated safe location, positioned 30 meters away from the entrance. The entirety of the evacuation route spanned a distance of 55 meters. The center of the classroom's chair case served as the designated starting point for all participants, clearly demarcated with markers. The safe location, where the evacuation route concluded, was similarly marked with two prominent indicators. The subjects were advised to move as quickly as possible to the finishing point upon hearing the fire alarm, which signaled the beginning of the test. The trained staff positioned at the endpoint recorded the response time using a handheld stopwatch. Time was measured in seconds, recognizing that even a few seconds in an emergency can be pivotal (Baldwin, 1994).

Statistical analyses

The JASP software (Jeffreys's Amazing Statistics Program, GNU Affero General Public License) version 0.18.3 was utilized for data analysis. The two-tailed Student's t-test was used to assess whether there is a significant difference between the means of two groups and to test hypotheses regarding the mean of a small sample drawn from a normally distributed population. The approach investigated differences between students who were physically active and those who were physically inactive. The variables of interest in this study included muscle power (measured by the standing long jump), muscle endurance (assessed through push-ups), and fire emergency response time, evaluated using a 55-meter movement time test. According to the American College of Sports Medicine (ACSM) Exercise Preparticipation Health Screening Questionnaire for Exercise Professionals (American College of Sports Medicine, 2020), the group was divided into two smaller groups: physically active participants (10 subjects) and physically inactive participants (11 subjects). The equality of variances for a variable calculated for two groups was evaluated using Levene's Test for Equality of Variances. The p-value significance threshold was set at $p \leq 0.05$. Cohen's effect size (d) was employed to quantify the discrepancies, categorizing them as follows: d < 0.2 (trivial or negligible effect), d = 0.2-0.5 (small effect), d = 0.5-0.8 (moderate effect), d = 0.8-1.3 (large effect), or d > 1.3 (very large effect), (Sullivan & Feinn, 2012).

Results

The descriptive statistics for active and inactive group is shown in Table 1.

Table 1. Descriptive statistics.

Variables	Active group (n=10)				Inactive group (n=11)			
	Mean	SD	SE	CV	Mean	SD	SE	CV
Standing broad jump (cm)	201.70	31.19	9.86	0.16	152.46	35.09	10.58	0.23
Push-ups (No.)	24.30	7.51	2.38	0.31	9.91	5.77	1.74	0.58
Movement 55m (s)	13.49	1.67	0.53	0.12	15.65	2.23	0.67	0.14

Participants who were physically active completed a 55-meter movement time test significantly ($p \leq 0.05$) faster and with a shorter emergency response time (Table 2, Figure 2). Second, physically active participants performed better on the standing broad jump test (Table 2, Figure 1). Finally, physically active participants performed better on the muscle endurance test (Table 2, Figure 1) than physically inactive participants. Additionally, a very large disparity was evident in the standing broad jump, while large differences were observed in push-up performance and emergency movement time. The primary hypothesis of the study was supported by the data, indicating that physically active participants exhibited faster emergency reaction times.

Table 2. Comparison between active and inactive firefighters.

Measure 1	Measure 2	t	df	p	Cohen's *d*
Standing broad jump - Active group	Standing broad jump - Inactive group	4.615	9	0.001	1.46
Push-ups - Active group	Push-ups - Inactive group	3.851	9	0.004	1.22
Movement 55m - Active group	Movement 55m - Inactive group	-2.73	9	0.023	-0.86

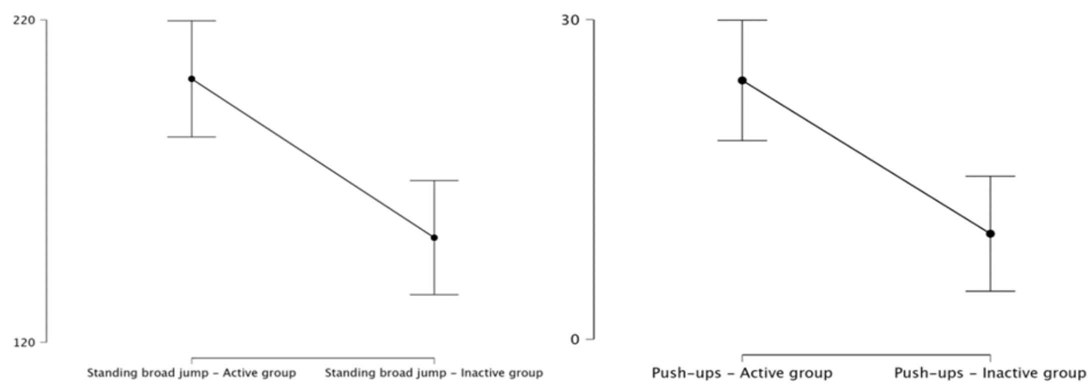

Figure 1. Descriptive plots for standing broad jump and push-ups.

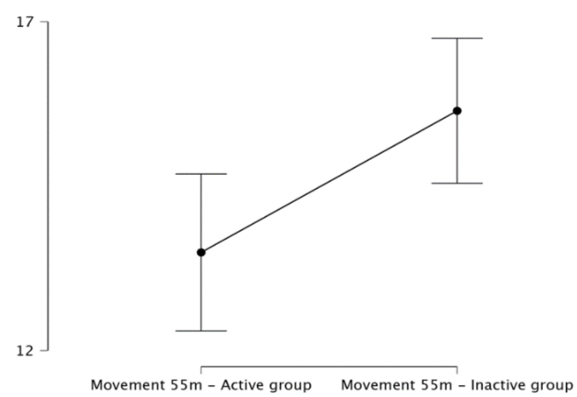

Figure 2. Descriptive plots for Movement time.

Discussion

The primary aim of this study was to investigate the potential influence of physical fitness variables, specifically muscle endurance and muscle power, on evacuation time. This investigation was based on the hypothesis that individuals with higher levels of physical fitness would complete evacuation routes more expeditiously than their less physically fit counterparts. While physical activity has yet to be formally acknowledged as a component of disaster preparedness, the findings presented herein suggest that physically active but untrained young adults may demonstrate improved performance in disaster evacuation scenarios.

Several institutions, exemplified by Boston University, advocate for an expeditious yet composed evacuation strategy: "Evacuate calmly and promptly upon activation of a fire alarm or carbon monoxide alarm" (Boston University). Extended evacuation durations may reflect a familiarity with fire evacuation protocols, accrued experience, and a deliberate, composed movement toward the designated exterior evacuation area, in accordance with the recommendations of these institutions. However, in actual evacuation scenarios, individuals typically prioritize expediently vacating the premises, potentially modifying expectations for a tranquil evacuation. Muscle power and endurance emerged as the key factors that exhibited notable distinctions between the two groups, along with a swifter emergency response observed among physically active participants. The muscle power test stands as one of the frequently utilized assessments to delineate the physical attributes of emergency personnel and serves as a pivotal performance indicator (Maupin et al., 2018). Because disaster-related situations call for high-intensity movements, power appears to be essential for emergency performance (Joseph et al., 2018). Peak power can be assessed through a range of methodologies, and forthcoming investigations could focus on techniques such as the vertical jump or the medicine ball throw test. These tests have the potential to elucidate whether muscle power directly influences emergency response capabilities.

Muscle endurance can be evaluated using various methods, and push-ups serve as a valuable performance metric. Elite tactical units have demonstrated superior muscular endurance in push-ups compared to the general population, making it a relevant and effective indicator of fitness (Maupin et al., 2018). The findings of this study provide evidence supporting the notion that endurance training enhances physical capacity and performance across a spectrum of emergency occupational responsibilities (Hendrickson et al., 2010).

One limitation of the study could be the lack of homogeneity among research participants in terms of age and fitness levels, potentially limiting the generalizability of the findings to the broader population of evacuees in typical building settings within a community. However, it is worth noting that the participants may better reflect the diverse demographics found on university campuses and similar structures. Despite the modest sample size of the study's participants, a comprehensive analysis was executed to depict a genuine scenario in which a singular ordinary university classroom could feasibly accommodate the specified number of individuals without exceeding its capacity.

The objective of this study was to determine whether a significant correlation existed between levels of physical activity and fire emergency response times. While performance ability remains critical for emergency teams, this study elucidated how certain aspects of physical fitness can impact initial fire emergency response time, thereby aiding in mitigating the effects of disasters (Mannion et al., 1999). The results of this study suggest that measures of muscle endurance and muscle power may be directly correlated with fire emergency response time.

Practical Implications

Every action outlined in each phase of disaster risk reduction should be taken seriously and routinely implemented to reduce the effects of any disaster. Health benefits of physical activity are very clear, while this study also ascertain strong connection between physical activity and emergency response (Warbuton &

Bredin, 2017). This study has demonstrated how some physical fitness factors, such as muscle power and muscle endurance, could influence emergency response times. Despite the absence of a mandate for physical activity among young adults and students, considering the demonstrated link between disaster response and physical activity, it may be advisable for both physically inactive participants in this study and their peers to consider adopting a more active lifestyle in the future. In addition to engaging in disaster preparedness training, which enhances performance during emergencies, individuals should prioritize physical activity to preserve their physical and mental well-being. This proactive approach ensures readiness to respond effectively during emergencies, potentially enabling individuals to save their own lives or the lives of others (Bajić, Veljović, & Bulajić, 2023). Finally, as corroborated by numerous studies referenced in this research, regular physical activity has the potential to preserve lives not only during disasters but also in non-crisis contexts, whereas sedentary behavior is posited to be intricately linked to morbidity, both directly and indirectly (Alvar, Sell & Deuster, 2017).

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Original article

Running performance of under-17 football players during official matches

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Abstract

The aim of this study was to determine whether there are differences in running performance among lines of the team (defense, midfield, and attack) during competitive activities of under-17 football players. The study involved 18 under-17 football players from the "Vojvodina" FC selection in Serbia, with an average age of 15.89±0.44 years. Depending on their position in the team, players were divided into three groups (defense, midfield, attack). Running performance were measured using the GPS device "Gpexe it". Data were collected from 25 matches during one season. The measured variables included total distance covered, distance covered in zone 4 (19.8-25.2 km/h), distance covered in zone 5 (over 25.2 km/h), number of accelerations, and number of decelerations. All variable values were normalized relative to the time spent on the field during each match. At a general level, the results found a statistically significant difference between the groups (team lines) for the mentioned variables ($p < 0.05$), except for the variable distance covered in zone 4. It can be concluded that these results could be used as norms for running performance during competitive activities of football players (U17 category). Additionally, based on the defined scope and intensity, these results can help in designing the training process to maximize the motor potential of under-17 football players.

Keywords: defense, midfield, attack, total distance, high-intensity distance.

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Introduction

In modern football, increasing emphasis is placed on the analysis of competitive activity in terms of movements. This includes total distance covered, running speed, number of duels, accelerations, decelerations, and many other indicators. These data can greatly define the level of running performance in matches, allowing sports professionals to prepare an adequate plan and program during the training process based on this information (McGuigan, 2017).

Various factors can influence the characteristics of volume and intensity during matches, such as the location of the match (home or away), altitude, pitch quality, opponent's quality or ranking, level of competition, match outcome (win, draw, loss), as well as the coach's role (formation, tactics, playing style) (Aquino et al., 2022). Additionally, factors like team's physical preparedness level, fatigue, match duration, and individual player abilities also play a significant role.

In addition to the total distance covered (volume), it has been found that the total distance covered at high intensity (over 19.8 km/h) increases with the age category of football players, while there is no significant difference in moderate-intensity distance (Vieira et al., 2019). One of the indicators considered as a factor of overall physical preparedness today is the total distance covered, while sprint distances and accelerations are the main physical determinants of performance in team sports (Haugen et al., 2014). The overall average distance covered by elite players during a match is between 10-13km (Bangsbo et al., 1991; Mohr et al., 2003; Krustrup et al., 2005; Bangsbo et al., 2006; Mascio & Bradley, 2013), while for goalkeepers, it's around 4 km. Categories of running performance in which players engage vary from author to author. For players competing in the U17 category (2x40 min), the average achieved values of running performance were: 8312±1054m for total distance covered, 6749±768 m for low-intensity running <13.0 km/h, 991±370 m for high-intensity running 13.1-16 km/h, 519±155 m for very high-intensity running 16.1-19 km/h, and 449±147 m for sprinting >19.1 km/h (Buchheit et al., 2010; Kádár et al., 2023).

In football, different positions in the team directly influence players movement activities. Accordingly, it has been found that central defenders cover a smaller total distance as well as a smaller distance at high intensity compared to players in other positions, which is closely related to their tactical duties (Bangsbo, 1994; Mohr et al., 2003; Krustrup et al., 2003). Additionally, central defenders are characterized by backward runs, lateral movements, and a high number of jumps, while full-backs (wing-backs) are characterized by high-intensity runs, sprints, mainly in straight-line movements. Midfielders achieve the highest values in the total distance covered compared to other positions in the team. However, differences in running performance can also exist within the same team line, with players in wide positions covering the greatest distance at high intensity (Carling et al., 2008). Central midfielders, in the defensive phase, are tasked with joining defensive players in preventing the opponent's attack, while in the attacking phase, their role is based on creating attacking actions. They are characterized by short sprints, changes of direction, and short distances of high intensity. Wingers and forwards achieve the highest running speeds in the game as well as frequency in high-intensity activities and sprints (Buchheit et al., 2010; Al Haddad et al., 2015; Izzo & Varde'i, 2017). Forwards are characterized by jumps, turns, curved and diagonal runs, playing in the final attacking zone, and their main task is to score goals and quickly evade opponents.

The aim of this study was to determine whether there are differences in movement activities among lines of the team (defense, midfield, and attack) during competitive activities. Running performance during competitive activities can be conducted through various parameters and methods. Monitoring the total distance covered and movements at high intensity during a match can provide insight into their individual characteristics. Tracking players' movements when they don't have the ball can reveal their ability in positioning, spatial movement, and collaboration with teammates. This includes analyzing defensive and offensive movements, as well as their ability to adhere to the team's tactics.

Methods

Experimental approach to the problem

The research belongs to the quantitative research approach, of a cross-sectional type. The time frame of the study encompasses one football season of the under-17 age group. The research design included measuring volume and intensity variables among participants from one team who were divided into three groups (team lines): defense (n=8), midfield (n=7), and attack (n=3).

Participants

The study involved 18 under-17 football players from "Vojvodina" FC selection in Serbia, with an average age of 15.89±0.44 years. Data were recorded from 25 matches during one season, only for players who started the matches. A total of 218 data points were collected, including 70 data points for defenders, 113 for midfielders, and 35 for attackers. At the beginning of the season, the average height of defenders was BH=176.61±6.96 cm, body mass BW=62.92±4.61 kg, for midfielders BH=173.58±4.41 cm, BW=65.36±5.36 kg, and for attackers BH=181.77±5.47 cm, BW=68.52±5.89 kg. The average time spent on the field by starting players was 84.13±22.32 min for defenders, 80.43±19.21 min for midfielders, and 81.74±18.81 min for attackers. This selection finished 5th in the Serbian U17 league. The study protocol was approved by the Ethics Committee of the Faculty of Sport, University "Union – Nikola Tesla" (approval number: 197-1/22). All participants signed written consent to participate in the research following the principles of the Helsinki Declaration.

Measurements and Procedures

The movement activities of "Vojvodina" FC players were monitored during official matches of the Serbian U17 league in the 2022/2023 season, starting from the sixth to the thirtieth round. In the first part of the season, the team played in a 1-4-4-2 formation, while in the second part, they used a 1-4-5-1 formation. To collect data, a GPS device branded "Gpexe it" (Figure 1) was used. This device, operating at 18Hz, was approved by FIFA for use in official matches. Before each match, starting players were provided with one vest and one GPS device. The devices were inserted into the vest, specifically into the pocket located on the player's back, between the shoulder blades. After each match, all devices were connected to a console, through which the data were transferred to the server using the "Gpexe Bridge" application. In a previous study conducted using the same 18Hz device, good to moderate validity and reliability were established for determining the distance covered (standard error of measurement SEE: 1.6-8.0%; coefficient of variation CV: 1.1-5.1%) and sprinting performance (SEE: 4.5-14.3%; CV: 3.1-7.5%) (Hope et al., 2018).

Image 1. "Gpexe It" device and vest.

Variables

The relative values of variables were obtained concerning the time players spent on the field during each match, aiming to provide a clearer and more precise picture of the volume and intensity in matches (Guerrero-Calderon et al., 2022).

The relative values of variables concerning the time spent on the field during the match are as follows:

- TD_r - Total distance covered/time, expressed in m/min;
- Speed_4_r - Distance covered in zone 4 recorded at a speed between 19.8 km/h-25.2 km/h / time, expressed in m/min;
- Speed_5_r - Distance covered in zone 5 recorded at a speed over 25.2 km/h / time, expressed in m/min;
- Acc_ec_r - Number of accelerations/time, expressed in n/min (acceleration is defined as any change in movement speed of 2.5m/s over a duration of 0.5s);
- Dec_ev_r - Number of decelerations/time, expressed in n/min (deceleration is defined as any change in movement speed of -2.5m/s over a duration of 0.5s).

Statistical analyses

For data processing, descriptive statistics were utilized (mean, standard deviation, coefficient of variation, minimum and maximum values, quartiles). To determine differences among the variables at the team line level (defense, midfield, attack), analysis of variance (ANOVA) with Bonferroni post-hoc test was employed. The significance threshold for statistical differences was set at $p < 0.05$. Eta squared (effect size) was calculated as the ratio of the sum of squares of deviations between different groups and the total sum of squares. Effect size criteria used for this research were 0.01 (small effect), 0.06 (medium), and 0.138 (large) (Pallant, 2011). Microsoft® Office Excel 2007 and SPSS for Windows, Release 17.0 (Copyright © SPSS Inc., 1989–2002) were used for data processing and analysis.

Results

In Table 1, descriptive indicators of the relative variables concerning the time players spent on the field during matches are presented. These results indicate that midfielders achieved the highest volume, i.e., total distance covered (114.38±8.54 m/min). Regarding high-intensity variables Speed 4_r and Speed_5_r, attackers achieved the highest values (5.57±7.88 m/min vs. 6.15±1.56 m/min), as well as for accelerations (Acc_ec_r = 0.30±0.10 n/min) and decelerations (Dec_ev_r = 0.47±0.15 n/min). The results of the variables in Table 1 can be converted into absolute values when multiplied by the time starting players spent on the field from the beginning of the match. For example, the total distance covered for midfielders during 80 minutes would be 9150 m, for attackers 8667 m for 82 minutes, and for defenders 8277 m for 84 minutes.

In Table 2, based on ANOVA, differences between groups for defined variables are presented. It was found that there is a statistically significant difference between groups for variables TD_r ($p < 0.000$), Speed_5_r ($p < 0.000$), Acc_ec_r ($p < 0.011$), and Dec_ev_r ($p < 0.000$), while there was no statistically significant difference for variable Speed_4_r. The actual difference between the mean values of groups for variables TD_r and Speed_5_r is large (eta squared = 0.17 vs. 0.20), while for variables Acc_ec_r and Dec_ev_r, it was medium (eta squared = 0.04 vs. 0.09).

Table 1. Basic descriptive statistics of relative values by team lines.

Variables	Team lines	Mean	SD	CV%	Min	Max
TD_r (m/min)	defense	98.53	13.73	13.93	46.80	124.47
	midfield	114.38	8.54	7.47	99.46	129.78
	attack	105.70	14.47	13.69	24.97	136.94
Speed_4_r (m/min)	defense	5.57	7.88	141.55	1.62	68.14
	midfield	5.31	1.96	36.94	1.99	10.28
	attack	6.15	1.46	23.70	1.91	11.74
Speed_5_ r (m/min)	defense	1.41	0.89	63.13	0.31	4.32
	midfield	0.56	0.42	74.34	0.00	1.88
	attack	1.43	0.76	52.99	0.07	3.55
Acc_ec_r (n/min)	defense	0.25	0.10	40.67	0.09	0.50
	midfield	0.31	0.13	41.24	0.07	0.62
	attack	0.30	0.10	32.78	0.03	0.67
Dec_ev_r (n/min)	defense	0.38	0.12	31.34	0.17	0.67
	midfield	0.42	0.12	27.86	0.18	0.75
	attack	0.47	0.15	31.38	0.13	0.93

TD_r – Relative total distance covered, **Speed_4_r –** Relative distance covered at a speed between 19.8-25.2 km/h, **Speed_5_r** – Relative distance covered at a speed over 25.2 km/h, **Acc_ec_r** – Relative number of accelerations, **Dec_ev_r** – Relative number of decelerations.

Table 2. Basic indicators of analysis of variance (ANOVA) for relative variable values.

		Sum of Squares	df	Mean Square	F	Sig.
TD_r (m/min)	Between Groups	7661.11	2	3830.56	22.69	**0.000**
	Within Groups	36331.12	215	168.98		
	Total	43992.23	217			
Speed_4_r (m/min)	Between Groups	27.494	2	13.75	0.63	0.533
	Within Groups	4686.93	215	21.800		
	Total	4714.43	217			
Speed_5_r (m/min)	Between Groups	30.02	2	15.01	27.43	**0.000**
	Within Groups	117.66	215	0.55		
	Total	147.69	217			
Acc_ec_r (n/min)	Between Groups	0.105	2	0.053	4.58	**0.011**
	Within Groups	2.48	215	0.012		
	Total	2.58	217			
Dec_ev_r (n/min)	Between Groups	0.38	2	0.190	11.00	**0.000**
	Within Groups	3.72	215	0.02		
	Total	4.10	217			

TD_r – Relative total distance covered, **Speed_4_r –** Relative distance covered at a speed between 19.8-25.2 km/h, **Speed_5_r** – Relative distance covered at a speed over 25.2 km/h, **Acc_ec_r** – Relative number of accelerations, **Dec_ev_r** – Relative number of decelerations.

In Table 3, differences between team lines for defined variables are presented. Regarding the total distance, it was found that there is a statistically significant difference between team lines, i.e., between defense and midfield ($p < 0.000$), defense and attack ($p < 0.001$), and midfield and attack ($p < 0.000$). As for the variable

Speed_5_r, there were statistically significant differences between defense and midfield players ($p < 0.000$) and midfield and attack players ($p < 0.000$). However, there was no statistically significant difference between defensive players and attackers ($p < 0.844$). For the acceleration variable, there was a statistically significant difference between defensive players on one hand, and midfield ($p < 0.009$) and attack players ($p < 0.009$) on the other hand. For the deceleration variable, there was a statistically significant difference between defensive players and attackers ($p < 0.000$).

Table 3. Differences of variables between team lines (ANOVA) with Bonferroni post-hoc test for relative variable values.

Variable			Mean Difference (I-J)	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
TD_r (m/min)	defense	midfield	-15.85*	2.35	-21.53	-10.17
		attack	-7.17*	2.05	-12.12	-2.21
	midfield	attack	8.68*	2.22	3.33	14.04
Speed_5_r (m/min)	defense	midfield	0.08*	0.13	0.52	1.17
		attack	-0.02	0.12	-0.30	0.26
	midfield	attack	-0.87*	0.13	-1.17	-0.56
Acc_ec_r (n/min)	defense	midfield	-0.05*	0.02	-0.10	0.00
		attack	-0.04*	0.02	-0.09	0.00
	midfield	attack	0.01	0.02	-0.04	0.05
Dec_ev_r (n/min)	defense	midfield	-0.05	0.02	-0.10	0.01
		attack	-0.10*	0.02	-0.15	-0.05
	midfield	attack	-0.05	0.02	-0.11	0.00

TD_r – Relative total distance covered, **Speed_5_r** – Relative distance covered at a speed over 25.2 km/h, **Acc_ec_r** – Relative number of accelerations, **Dec_ev_r** – Relative number of decelerations.

Discussion

The aim of this study was to determine whether there are differences in running performance among lines of the team (defense, midfield, and attack) during competitive activities of under-17 football players. In this research, it was found that there is a statistically significant difference in volume, i.e., in TD_r, between defense, midfield, and attack. These results are consistent with previous studies examining similar characteristics in elite Polish and Danish youth football players. Specifically, the analysis of Polish and Danish players' results showed that the total distance covered is higher in midfield players compared to other positions. Additionally, the results of this study align with previous research where midfield players achieved the highest total distance of 114.38 m/min. This difference was expected due to the nature of the midfield position, which involves both offensive and defensive duties, covering the largest area of the field.

When it comes to differences in distance covered at high intensity (Speed_5_r), over 25.1 km/h, it is observed that defensive and offensive players statistically covered a greater distance than midfield players, even by 60%. Data analysis leads to the conclusion that defensive players have high values in the Speed_5_r variable due to the full-back positions. Nowadays, full-backs in modern football, in addition to defensive actions, also participate in attacking plays and have a more prominent role in the attacking phase, mostly through wing plays and crosses. Distances covered by players in these situations are between 60-80m and are mostly at high intensity or sprinting, directly linked to the success of attacking plays and faster positioning in the defensive phase. This has been confirmed in previous studies with senior (Mallo et al., 2015; Modric et al., 2019, 2020) and youth-level players (Buchheit et al., 2010; Dolanski et al., 2018).

In the variables of acceleration and deceleration, midfielders and attackers achieved higher results compared to defense. These results were expected due to the nature of the position, frequent changes of direction, acceleration during goal-scoring attempts, evading opponents, creating pressure, and stealing the ball from the opponent. Midfielders and attackers were the most exposed to acceleration and deceleration activities. This data can be used in individual training program planning. The data obtained in this study, defining the volume and intensity by team lines, can also be used in training load management.

As a limitation of this study, the sampling method can be considered, i.e., to make the results more applicable, it is necessary to increase the representativeness (more clubs from the same age category) and the sample size (more players divided by position).

Practical Implications

Based on the data obtained in this study, the workload in terms of volume and intensity during competitive activities of U17 football players was defined. Differences between team lines were also shown. All of this can greatly benefit the coach in managing the workload during the training process to maximize the players' motor potential. Identifying certain deficiencies in defined variables can also be useful for coaches in individual work. The combination of these aspects allows for a comprehensive analysis of U17 football players movements during competitive activities and provides a basis for developing personalized training programs and improving their on-field performance. Table 4 shows the relative quartile values of the variables in relation to the team line. These values of defined variables can have practical application in ranking the running performance of U17 players according to their position on the team.

Table 4. Relative values of variables in relation to team lines displayed through quartile differences.

Team lines	Percentile	TD_r (m/min)	Speed_4_r (m/min)	Speed_5_ r (m/min)	Acc_ec_r (n/min)	Dec_ev_r (n/min)
defense	<20	≤87.75	≤2.85	≤0.64	≤0.16	≤0.27
	20-40	87.76-93.86	2.86-3.48	0.65-1.09	0.17-0.21	0.28-0.33
	40-60	93.87-102.27	3.49-4.86	1.1-1.32	0.22-0.27	0.34-0.38
	60-80	102.28-110.38	4.87-6.57	1.33-2.01	0.28-0.34	0.39-0.51
	80≤	110.39≤	6.58≤	2.02≤	0.35≤	0.52≤
midfield	<20	≤106.03	≤3.27	≤0.15	≤0.21	≤0.33
	20-40	106.04-110.37	3.28-4.77	0.16-0.41	0.22-0.24	0.34-0.38
	40-60	110.38-115.46	4.78-5.68	0.42-0.57	0.25-0.33	0.39-0.44
	60-80	115.47-124.06	5.69-6.81	0.58-0.98	0.34-0.43	0.45-0.54
	80≤	124.07≤	6.82≤	0.99≤	0.44≤	0.55≤
attack	<20	≤97.60	≤4.89	≤0.78	≤0.21	≤0.35
	20-40	97.61-103.49	4.9-5.84	0.79-1.19	0.22-0.28	0.36-0.41
	40-60	103.5-110.34	5.85-6.43	1.2-1.54	0.29-0.32	0.42-0.51
	60-80	110.35-114.96	6.44-7.20	1.55-2.06	0.33-0.37	0.52-0.60
	80≤	114.97≤	7.21≤	2.07≤	0.38≤	0.61≤

TD_r – Relative total distance covered, **Speed_4_r** – Relative distance covered at a speed between 19.8-25.2 km/h, **Speed_5_r** – Relative distance covered at a speed over 25.2 km/h, **Acc_ec_r** – Relative number of accelerations, **Dec_ev_r** – Relative number of decelerations.

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Original article

Relationships between Relative Strength, Power, and Speed among NCAA Division II Men's Lacrosse Athletes

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Abstract

Lacrosse players are required to perform multiple sprints and changes of direction over the course of a game. These skills are reliant on the ability to rapidly produce lower-body force to be successful. Currently, little research examining the relationship between specific performance indicators and relative strength within this population exists. The purpose of this study was to investigate relationships between measures of lower-body strength and power to sprinting and change of direction speed (CODS) among male lacrosse players. Archived data for (n= 18) NCAA Division II male lacrosse athletes were used for this analysis. Lower-body strength was assessed using a one-repetition maximum back squat. Power was assessed using a countermovement jump (CMJ), squat jump (SJ), and standing long jump (SLJ). Sprint speed at 10 and 30 yds (i.e., 9.14 and 27.43 m) and CODS (i.e., T-Test (TT) and modified T-Test (MTT) were also assessed. Pearson's correlation was used to determine relationships between lower-body strength and power to sprint speed and CODS. Significant relationships ($r = -0.51$ - -0.64, $p \leq 0.05$) were discovered between all measures of power and CODS, as well as SLJ and sprint speed ($r = -0.51$; $p = 0.05$ and -0.67; $p \leq -0.01$, respectively). No significant relationships between relative strength and any measures of sprint speed or CODS were discovered. Although relative strength was not directly related to sprint speed or CODS performance, it may indirectly affect these measures based on its relationship to power, and power's relationship to sprint and CODS performance.

Keywords: Strength and conditioning, Performance optimization, Field sports, Maximum power, Linear speed, Agility

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Introduction

Lacrosse is a sport characterized by intermittent high-intensity bouts of sprinting and rapid changes of direction (Calder, 2018). Previous research suggests these physical qualities are underpinned by both absolute lower-body strength and power, therefore, based on empirical and observational evidence it appears that in order to optimize performance in the game of lacrosse lower-body strength, power, and speed are essential (Collins et al., 2014; Delaney et al., 2015; Gutowski & Rosene, 2011; Kulakowski et al., 2020; Lockie et al., 2016; Miller, 2012; Sheppard et al., 2014; Styles et al., 2016). However, the relationships between these variables have not been fully explored within this sport.

Previous research has reported that linear sprint speed and change of direction speed (CODS) is related to the expression of absolute and relative lower-body strength and power among a variety of field and court-based athletes, such as soccer and volleyball (Andersen et al., 2018; Lockie et al., 2018; McFarland et al., 2016; Tramel et al., 2019). In fact, Andersen et al. (2018) found significant correlations between relative lower-body strength and power to linear and change of direction speed (CODS) among a group of Division II female soccer players. Similar findings have been reported by Lockie et al. (2018) and McFarland et al. (2016) in separate studies examining the relationships between components of linear speed, lower-body power, and CODS in diverse samples of collegiate soccer athletes (Lockie et al., 2018; McFarland et al., 2016). Both studies observed significant small-moderate relationships between lower-body power to linear and CODS ($r = -0.443$ to -0.751; $p < 0.05$, respectively). Additionally, Tramel et al. (2019) reported large, significant correlations between absolute and relative strength and measures of power as measured by a repeat jump test, as well as CODS as measured by the modified t-test (MTT) and 505-agility test (2019). Overall, these results indicate that regardless of sport, strength and conditioning professionals should emphasize the development of absolute and relative lower-body strength to improve measures of power, linear speed, and CODS in collegiate athletes.

While the relationships between lower-body strength and power to speed have been explored in other sports, few studies have investigated these correlations among lacrosse athletes. This is a notable observation due to the nature of the sport, the physical demands, and the qualities needed to excel (Collins et al., 2014; Delaney et al., 2015; Gutowski & Rosene, 2011; Kulakowski et al., 2020; Lockie et al., 2016; Miller, 2012; Sheppard et al., 2014; Sheppard & Young, 2006; Styles et al., 2016). A study conducted by Kulakowski et al. (2020) reported that measures of relative lower-body power (relative countermovement jump (CMJ) and squat jump (SJ)) were significantly related to linear speed and CODS in Division II female lacrosse athletes (Kulakowski et al., 2020). In addition to these findings the authors reported that only the CMJ ($r = -.506$, $p < 0.05$) and relative CMJ ($r = -.491$, $p = 0.05$) were related to 10m sprint speed. Standing long jump (SLJ) distance was significantly related to all CODS tests ($r = -.601 - -.684$, $p < 0.01$) and 30m speed ($r = -.528$, $p < 0.05$), while relative SLJ distance was significantly correlated with 5-0-5 speed ($r = -.642$, $p < 0.01$). Furthermore, the authors did not observe relationships between measures of absolute power and any sprint or CODS test ($r = -.101 - -.310$, $p > 0.05$). However, to the authors' knowledge, the relationships between lower-body strength and power measures to specific speed qualities has not been thoroughly addressed among male lacrosse players. This information may be of value when attempting to assess and improve upon athletic potential for athletes within this sport.

Additionally, previous research has suggested that individuals with greater relative strength produce greater external mechanical power during a vertical jump, jump higher, and sprint faster than those with less relative strength (Andersen et al., 2018; Kulakowski et al., 2020; McBride et al., 2009; Tramel et al., 2019). Based on previous research among female lacrosse players which has observed significant relationships between lower-body power and sprint and CODS ability, it would seem likely that relative strength and power may be essential for CODS performance ((Kulakowski et al., 2020; Sell et al., 2018; Tramel et al., 2019). To this end, research has revealed significant relationships between maximal lower-body strength, relative lower-body strength (RLBS), and CODS performance in elite-level female athletes (Polley et al., 2015; Sell et al., 2018; Suchomel et al., 2016). However, with respect to males, recent findings suggest that relationships between strength, power, and CODS performance are generally weak (McFarland et al., 2016).

Assessing relative strength rather than absolute strength of an individual is likely to be more important in certain sports, like lacrosse, where one must move their own body mass (e.g., sprinting, jumping, changing direction) (Sullivan & Feinn, 2012). Therefore, the purpose of this study was to determine if significant relationships exist between relative strength, lower-body power, linear speed, and CODS in Division II collegiate men's lacrosse athletes. This information could potentially be used by sports performance professionals to determine which lower-body strength and power assessments are most related to linear speed and CODS performance. Thus, the authors hypothesize that significant relationships will be observed between measures of relative muscular strength and lower-body power, and between lower-body power, linear speed, and CODS.

Methods

Participants

Anonymized archived data from 18 Division II collegiate men's lacrosse players (age: 19.2 ± 1.2 years; height: 181.3 ± 7.1 cm; body mass: 77.9 ± 10.4 kgs), who participated in normal pre-season testing, were analyzed for this study. All participants were required to be a member of the university's lacrosse team, injury free, and over 18 years of age, and fully participating in training at the time of testing to be included in this analysis. All participants had medical clearance for intercollegiate athletic participation, as well as read and signed consent forms to participate in athletics. The athletic department at the respective university also distributed written consent forms to the athletes at the start of the academic year to obtain permission to use any data collected from via normal testing and training procedures to potentially be used for research purposes. As such, the institutional ethics committee approved the use of pre-existing data for analysis. Each player also completed the university-mandated physical examination and read and signed the university consent and medical forms for participation in collegiate athletics.

Measurements and Procedures

Data was collected in the pre-season over two days, with 48-hours between sessions. All anthropometric, power, and CODS assessments were performed on the first day, while strength and sprinting speed assessments were performed on the second day. The only data used were of those athletes that were able to complete all tests relevant to this study. Each session included a ten-minute standardized dynamic warm-up which included low aerobic intensity jogging, a sport-specific dynamic stretching protocol, and ended with participants performing assessment-specific exercises which included various bodyweight squats, lunges, and jumps. Participants were then provided full instruction on how to perform each test and were allowed up to two practice trials for each. The first session included anthropometric, lower-body power, and CODS measurements in the following order: height (Ht), body mass (BM), SJ, CMJ, and SLJ followed by the T-Test (TT) and MTT. The second testing session included absolute lower-body strength (LBS) and RLBS measurements which were assessed by a 1RM barbell back squat and linear sprint tests assessed at 10 and 30 yds. The following is a detailed description of each valid and reliable method utilized to assess participants within this investigation in the appropriate testing order.

Anthropometrics

Height (cm) and body mass (kg) were measured on a doctor's beam scale (Cardinal; Detecto Scale Co, Webb City, MO, USA) (Andersen et al., 2018; Calder, 2018).

Lower-body power

Vertical jump height for both the SJ and CMJ was measured using a jump mat (Just Jump, Probotics Inc., Huntsville, Al, USA) (Lockie et al., 2016; Miller, 2012). For both tests, athletes were instructed to stand in the center of the jump mat with their hands on their hips. For the SJ, athletes were instructed to squat until they achieved a 90-degree knee angle, pause for approximately 2 sec and while keeping the hands on the hips jump as high as possible, before landing back in the center of the mat in an athletic stance (i.e., head up, chest up, and a slight bend in the ankles, knees and hips) (Lockie et al., 2016). For the CMJ, athletes were also instructed to stand in the middle of the mat with hands on the hips, and when ready, jump as high as possible while minimizing the time between the eccentric and concentric muscle actions (Lockie et al., 2016). Each athlete performed SJ and CMJ in a randomized order and were given three attempts for each jump. The best attempt for each jump was recorded. The height jumped was then measured in inches and later converted to centimeters.

Standing long jump (SLJ): SLJ was used as an assessment of horizontal lower-body power and participants were allowed three attempts. Participants were instructed to stand at the starting line with their feet shoulder-width apart, bend at the knee and use an arm swing, and jump as far forward as possible in one motion. The distance jumped was then measured in inches and later converted to centimeters.

Change-of-direction speed

On the second day, the TT was used to measure each athlete's ability to perform multi-directional movements (i.e., forward sprint, backpedal, and side shuffles) (Figure 1). As described by Kulakowski et al. (2020), the TT required the participant to sprint forward 10 yds (9.14m) to a center cone and touch said cone with right hand, immediately shuffle to the left 5 yds (4.57m to touch a cone with their left hand and immediately shuffle to the right 10 yds (9.14m) to touch the third cone with their right hand. After the second shuffle, the athlete shuffled left towards the middle cone, touched the cone with their left hand and backpedaled to the same cone they started the test, covering a total of 40 yds (36.56m). Participants were instructed to not cross their feet while shuffling, touch all cones, and face forward for the entirety of the test. If the subject failed to do these actions the test was omitted and repeated after three minutes. The best of three trials were recorded and rounded to the nearest 0.10 sec.

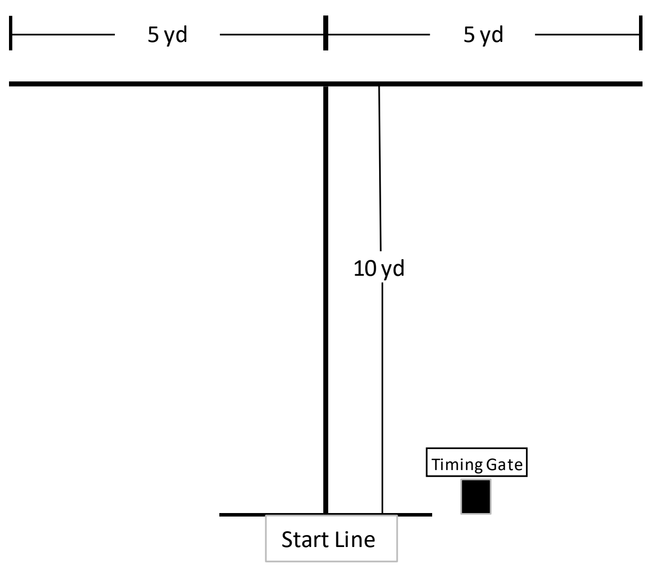

Figure 1. T-Test Layout. Adapted from Kulakowski et al. (2020).

Modified T-test: The MTT was performed in the same manner as the traditional T-test but required half of the distances be covered (Figure 2). This assessment requires the participant to sprint forward 5 yds (4.57m to a center cone and touch the cone with the right hand, immediately shuffle to the left 2.5 yds (2.28m) to touch a cone with the left hand and immediately shuffle to the right 5 yds (4.57m to touch the third cone with the right hand. After the second shuffle, the athlete shuffled left towards the middle cone, touched the cone with their left hand and backpedaled to the start cone, covering a total of 20 yds (18.28m). Participants were allowed two attempts for each assessment with the best score being recorded. Previous research suggests the MTT may be more advantageous compared to a TT as the shorter distances better mimics the COD requirements of most field-based sports (7, 26). The best of three trials were recorded and rounded to the nearest 0.10 sec.

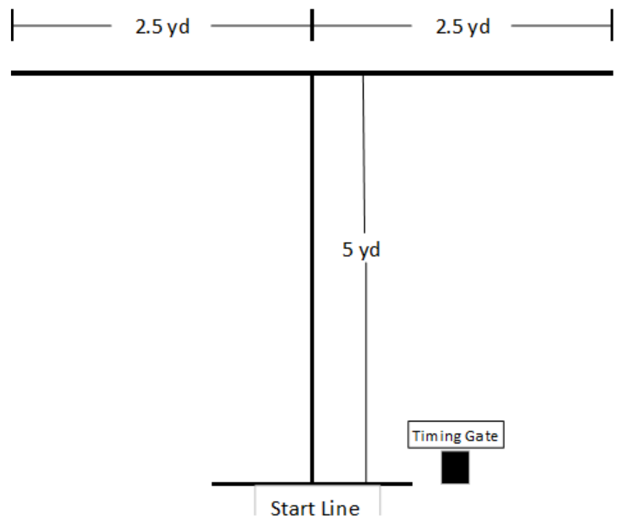

Figure 2. Modified T-Test Layout. Adapted from Kulakowski et al. (2020).

Maximal Lower Body Strength

First, maximal LBS was assessed via the 1RM barbell back squat test. For this assessment, weights were assigned based on participant's data from a previous 1RM barbell back squat test performed during an earlier strength development block. Before performing maximal back squat testing athletes were instructed in lifting protocol and warm-up. A dynamic warm-up was performed before any lifting occurred, led by strength and conditioning staff. The max protocol was as follows, for a lift to be counted as successful athletes had to reach a position where the quadriceps were parallel to the ground or lower, as judged by strength and conditioning staff. When warming-up, athletes with pervious maxes were to perform 5 reps at 50% 1RM, 3 reps 75% 1RM, 2 reps, ~85%-90% 1RM, then 1 rep until 1RM was found. This warm-up protocol is agreeable with current approaches within the field of lacrosse strength and conditioning (5). Athletes with no previous recorded 1RM were instructed to use the same warm-up protocol but to make estimations on weights that should be lifted based off previous resistance training cycles. Athletes were allowed 3 attempts to record a successful 1RM. LBS and RLBS measurements were assessed by a 1RM barbell back squat. Relative strength or RLBS was calculated for each athlete with the following equation (kilograms lifted)/(body mass (kg)).

Linear Sprint Speed

Split times for linear sprint speed were measured over a 10 yd (9.14m) and 30 yd (27.43 m) distance. The time required for participants to cover the first 10 yds and the total 30 yds was recorded to the nearest 0.10 sec using valid and reliable electronic timing system (TC-System, Brower Timing Systems, Draper, UT, USA) (Andersen et al., 2018). The best of three trials were recorded as the athlete's best score and used for analysis.

Statistical analyses

All statistical analyses were computed using PASW software version 24.0 (SPSS Inc, Chicago, IL, USA). Descriptive statistics (mean ± standard deviation (SD)) along with effect sizes were calculated for each variable. Pearson's correlation was used to find relationships between relative lower-body strength, power measurements, linear sprint speed, and CODS tests. Statistical significance was set at $p \leq 0.05$. The strengths of each correlation value were reported as follows: 0 to 0.30, or 0 to -0.30 was considered small; 0.31 to 0.49, or -0.31 to -0.49 was considered moderate; 0.50 to 0.69 or -0.50 to -0.69 was considered large; 0.70 to 0.89 or -0.70 to -0.89 was considered very large; and 0.90 to 1.0 or -0.90 to -1.0 a near perfect correlation (Sullivan & Feinn, 2012).

Results

Descriptive data for all assessments are presented in Table 1.

Table 1. Descriptive Statistics for sample (n = 18).

Variable	Minimum	Maximum	Mean ± SD	95% CI	ES	CV
Age (yrs.)	18	22	19.2 ± 1.2	18.6 to 19.8	0.996	6.3%
Ht (cm)	165.1	193.0	181.3 ± 7.1	177.8 to 184.9	0.999	3.9%
BM (kg)	61.2	106.6	77.9 ± 10.4	72.7 to 83.1	0.984	13.3%
BMI	19.9	31.0	23.7 ± 2.9	22.3 to 25.1	0.986	12.1%
LBS (kg)	81.7	174.6	113.1 ± 23.5	223.7 to 275.2	0.961	20.8%
RLBS (kg/BM)	1.2	1.9	1.5 ± 0.2	1.4 to 1.6	0.982	13.9%
CMJ (cm)	41.4	63.3	54.1 ± 5.1	20.4 to 22.2	0.992	9.2%
SJ (cm)	41.7	61.5	51.3 ± 4.8	19.3 to 21.2	0.992	9.5%
SLJ (cm)	196.9	271.8	243.1 ± 15.5	92.7 to 98.7	0.996	6.4%
TT (s)	9.1	10.7	9.8 ± 0.5	9.6 to 10.1	0.98	5.1%
MTT (s)	8.3	9.4	8.8 ± 0.3	8.7 to 8.9	0.998	3.3%
10 yds (s)	1.4	1.9	1.5 ± 0.1	1.4 to 1.6	0.995	7.1%
30 yds (s)	3.5	4.2	3.8 ± 0.2	3.8 to 3.9	0.998	4.0%

All strength and power measurements in relation to COD and linear speeds are displayed in Table 2. No significant relationships between relative lower-body strength (RLBS) and any sprint or CODS tests were discovered ($p = 0.27 – 0.92$). However, significant moderate positive relationships were observed between RLBS and power as measured by the SJ ($p = 0.02$) (Figure 1.). Additionally, RLBS did not show significant relationships to any other measure of lower-body power ($p = 0.08 – 0.42$). Significant moderate negative correlations were discovered between all measures of lower-body power and CODS (TT) ($p = 0.01 – 0.03$). Additionally, significant moderate negative correlations were also observed between all measures of lower-body power and 27.43 m linear sprint speeds ($p = 0.00 – 0.03$). However, the only measure of power that correlated to 9.14 m linear sprint speed was the SLJ ($p = 0.02$). In short, these results show that RLBS is related to power, and power is related to linear sprint speed, which may influence CODS ability to a degree.

Table 2. Correlations between measures of strength and power to linear and change of direction speed.

Variable	TT (s)	MTT (s)	10 yd (s)	30 yd (s)
LBS	-.094	.145	-.294	-.243
RLBS	-.273	-.025	-.203	-.263
CMJ (cm)	-.510*	-.318	-.438	-.514*
SJ	-.634**	-.260	-.311	-.556*
SLJ	-.636**	-.507*	-.536*	-.671**

Note: * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$

Discussion

The purpose of the current study was to investigate the relationships between lower-body strength and measures of power, linear speed, and CODS among Division II men's lacrosse players. The primary findings of this research identified significant, large negative correlations between SLJ, linear sprint speed, and CODS. Significant, large negative correlations were also identified between CMJ and SJ height, and TT and 30 yd linear sprint speed. Significant, moderate positive correlations between RLBS and SJ. However, no significant correlation between LBS and any measure of power, linear speed, or CODS were identified. Therefore, the results of the current study suggest that emphasizing the development of RLBS, and vertical and horizontal power production may improve both sprint and CODS ability within this population. Additionally, these findings may be beneficial for strength and conditioning professionals working to determine which athletic qualities are most related to those which strongly influence success within the sport of lacrosse.

Previous studies have identified relationships between LBS, RLBS, and various measures of power (Andersen et al., 2018; Nimphius et al., 2010; Sullivan & Feinn, 2012). Though the results of the current study did not identify any correlations between LBS and any measurement of power, there were moderate positive correlations between RLBS and SJ. Although no direct relationships between RLBS and speed were observed within this study, the results suggest that emphasizing the development of RLBS within the collegiate male lacrosse population may result in improved concentric force production as assessed by the SJ and translates to increased power- and speed production. This is similar to an investigation conducted by Anderson et. al. (2018) which reported large to very large correlations between relative strength and vertical jump but no correlation with absolute strength suggesting that improved relative strength may help improve on-field performance more than development of absolute strength. Kulakowski et. al. (2020) also revealed a significant relationship between relative power measures (CMJ and SJ) and all CODS and sprint speeds above 10m and no relationships from absolute power measures. Previous research suggests that improvement in lower-body power may improve a lacrosse athlete's CODS ability and linear speed (Andersen et al., 2018; Lockie et al., 2018; McFarland et al., 2016; Sheppard et al., 2014; Sullivan & Feinn, 2012). Findings from the current study provide further evidence that CODS is significantly influenced by the ability to generate higher levels of force in a short amount of time with SJ and CMJ being significantly related to TT and CODS alone, and SLJ being related to both CODS test. Regarding men's lacrosse, this relationship may be due to the demands of performing quick sprints every few seconds while performing high intensity changes of direction from both a static and dynamic start. It also reveals that SJ is a quality that coaches may want to consider when tailoring to collegiate male lacrosse athletes.

The relationships between lower-body power and linear sprint speed have been well-reported (Kulakowski et al., 2020; NCAA 2015, Nimphius et al., 2010). The results of the current study identified significant large negative relationships between SLJ and linear sprint speeds over 10 and 30 yds. Additionally, significant large negative correlations between CMJ and SJ height and 30 yd sprints were also identified. These findings are similar to McFarland et al, (2016) who found moderate negative correlations between 10m and 30m sprints with CMJ and SJ among male college soccer athletes. Additionally, these results suggest that SLJ may be better to include in a testing battery as it is more closely related to other skills required to be successful in lacrosse and other field-based sports, specifically linear sprint speed, but that CMJ and/or SJ may be used as a predictor for 30 yd sprinting performance. Findings from the current study suggest that emphasizing RLBS development within collegiate male lacrosse populations has the potential to improve concentric power production, sprint ability, and likely contributes to the athletic success within the sport of lacrosse. The relationships between lower body power and CODS have also been the focus of multiple studies ((Delaney et al., 2015; Hammami et al., 2018; Keiner et al., 2014). The results of the current study revealed CMJ and SJ height had large negative correlations with TT but not MTT. Moderate negative relationships between SLJ and both measurements of CODS were also shown. These findings are similar to Kulakowski et al, (10) who reported moderate negative relationships between SBJ and CODS (5-0-5, TT, MTT) among Division II female lacrosse players.

Significant moderate negative relationships between all measures of power and 27.43 m linear sprint speed were identified within the current study. However, SLJ performance was the only measure of power that was significantly related to 9.14 m linear sprint speed and that relationship was moderately negative. Several of these findings are supported by research within the field which has examined lower-body power measures to sprint and CODS among female lacrosse athletes and soccer players ((Kulakowski et al., 2020; Lockie et al., 2016; McFarland et al., 2016). Within the prior studies, researchers aimed to determine the relationship between lower-body power measures to sprint and CODS and concluded that results from measures such as SJ, CMJ, and SLJ could reflect sprint and CODS ability. However, there was a singular nuanced finding within the current study which translates to the sport of lacrosse and can alter methods for assessing and developing lacrosse athletes. This finding revolves around the relationship between RLBS and power which at its most fundamental level can be translated as a relationship between power and CODS.

Although sport-specific actions in lacrosse and many other field-based sports are dynamic in nature, the result of our analysis provides further evidence of the importance of developing concentric strength. Furthermore, and contrary to popular belief, this study highlights the underpinnings that concentric and dynamic force production has on the ability to achieve higher maximum velocities as expressed by the 30 yd linear sprint speed. Significant moderate positive relationships were identified between 10 and 30 yd linear sprint performance and TT and MTT performance. This suggests that male lacrosse athletes can maintain or develop max velocity abilities by working on accelerative abilities. Sport coaches and strength coaches can benefit from this information to improve current approaches for developing athletes. Additionally, the relationship between TT and MTT suggests that athletes can develop and maintain CODS while working on quick change ability from varying distances. This is beneficial for sport coaches and strength coaches as MTT better mimics most field-based sports but to achieve change of direction ability a TT is just as beneficial. Furthermore, significant moderate relationships between 27.43 m linear sprint speed and TT performance were identified. This finding may be useful for positions in men's lacrosse that require the athlete to achieve maximal velocities while approaching to perform extended CODS more often than other positions.

This study has limitations that should be noted. Due to the relatively small sample size of participants in this study, it may be beneficial for future research to include larger sample sizes by coordinating and collaborating with other teams and universities. In addition to providing a more robust sample, this would also allow for a more heterogeneous dataset than the one utilized in the current study. A second limitation of the current study involves information regarding the sample itself. In the future, it may be beneficial to account for biological age, training age, role on team, and playing experience, and to examine their interactions and influence on measures of physical performance. Not only will this assist research groups with providing more context to support their findings, but it may also assist practitioners in the field with determining the best approaches for developing their respective teams. Finally, the large number of correlations performed may have caused some spurious correlations to occur. However, upon review it does appear that the data trends in a general direction and those correlations observed and reported do not simply appear to be random chance.

In conclusion, higher RLBS is related to greater SJ performance but was not found to be directly or significantly related to linear speed or CODS performance. However, it is possible that RLBS may indirectly affect these measures based on its relationship to power. Additionally, greater SLJ distance is related to enhanced CODS and linear sprint speed. Thus, these results suggest that strength and conditioning professionals should be aware of these relationships when working with collegiate Division II male lacrosse athletes. Additionally, the findings from this study also provides strength and conditioning professionals with valuable information to improve their current approaches for developing athletes and ensuring that they are within normal ranges for strength, power, linear speed, and CODS. Therefore, while focusing on lower-body power development is a key component in preparing male lacrosse athletes for their sport, strength and conditioning professionals should also aim to improve relative strength as well.

Practical Implications

Collectively, these findings can be utilized to further benefit the development of sport specific training approaches aimed at improving athletic performance within the sport of lacrosse. To be specific, sports performance professionals within the sport of lacrosse should emphasize the development of relative lower body strength, vertical and horizontal force production, and vertical power production capabilities. After these athletic qualities have been developed to an appreciable level, it is recommended that the training program aims to enhance the transfer of those general athletic qualities to those which are more specific to the sport of lacrosse.

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Original article

How old are Elite Olympic swimmers?

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Abstract

The primary aim of this research is to determine the age of best Olympic swimmers. Secondary aim is to determine the qualitative and quantitative data's considering the current age in relation to the criteria of winners, medalists, and non-medal finalists at the last three Olympics (London 2012, Rio 2016 and Tokyo 2021) considering gender, distance and stroke. In summary, the average age of all finalists in men was 24.1 ± 3.6 years, with the level of the range from 20.5 to 27.6 years, while in women it was 23.0 ± 3.7, with a range of 19.3 to 26.7 years, and the age of elite Olympic male and female swimmers is statistically significantly different. Also, it was found that sprinters are statistically significantly older, regardless of gender, while no difference was found between middle- and long-distance swimmers. Among the medalists, sprinters are the oldest, regardless of gender, which is mostly observed for the distance of 50m freestyle (men 27.9±2.8, women 26.1±1.6 years). In relation to different techniques, among male swimmers, breaststroke swimmers are the oldest (25.0 years), while freestyle swimmers are the oldest among female swimmers (23.2 years). The results of the regression equations showed that the average age of swimmers at the next Olympic Games in Paris in 2024 will be 24.3 years, but that the average age of female swimmers will be 24.2 years (almost equal to male swimmers). In general, it could be concluded that there is a slight tendency for top female Olympic swimmers to get older, while this tendency has not been established for male swimmers.

Keywords: Olympic athletes, swimmers, age of athletes

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Introduction

Sport, as an integral part of human society, has its own stages and trends of development, which are specific for each sport or historical period of human civilization (Lonh, 2021). Top sports results could be usually achieved in a period that is biologically recognized as the period of youth or youth adult stage of life (Allen & Hopkins, 2015). The phenomenology of the career of top athletes, including the continuous monitoring and determination of the characteristics of the relationship between age and the potential for achieving top sports results, has been done in different sports, especially in individual (Gorzi et al., 2022).

Swimming is a historically important skill that man had to dominate in the ontogenetic aspect at the practical level. In other words, he had to master the skills of learning to swim. This is probably the most important reason why swimming has always had a significant social and educational role in human history, so it has been recognized as one of the sports that has been on the program of the modern Olympic Games since the very beginning i.e. from Athens 1986 (Lohn, 2021).

Sports experience and knowledge of the age at which elite swimmers achieve peak performance is very important for of the training process in terms of the organization multi-year planning and programming. This information is essential for the creation of long-term athlete development programs, for the selection of fundamentally important annual periods, and for the strategic decisions regarding the organization of preparation and competition phases. Also, the given data on the swimming peak performance age are important for the needs of career management in terms of planning the distribution of material and financial resources, as well as for the organization of the entire training technology system of a particular club or national association. Generally speaking, a complete phasing of the phenomenology of the relationship between the age of a top swimmer and his/hers maximum competitive performance as a function of technique and/or swimming race should be useful for monitoring the athlete's potential, result progression, stage level of achievement and identification of talents.

Identification of the optimal age of swimmers for achieving top results as a function of gender, competitive level, variability in race distance and stroke, represents a legitimate and current area of research in swimming science (Mallett et al., 2021; Dopsaj et al., 2023). Age, as a general chronological data, remains the most available data of all athlete characteristics, reflecting and supporting availability for their contribution to the prediction of competitive performance.

The primary aim of this paper is to determine the current data on the age of best Olympic swimmers i.e. Olympic finalists, as a category of top best swimmers. Secondary aim is to determine the qualitative and quantitative data's considering the current age in relation to the strata of winners, medallists, and generally finalists at the last three Olympics (London 2012, Rio 2016 and Tokyo 2021) as a function of gender, swimming distance and swimming technique. The obtained findings could help sports scientists, swimming researchers, coaches, and swimmers themselves with new information and a new perspective on the optimal age of Olympic-class swimmers.

Methods

Experimental approach to the problem

This research was carried out using a non-experimental method, and it belongs to the category of fundamentally oriented research.

Measurements and Procedures

The paper examines the ages of swimmers participating in the finale races (Males = 41 races, Females = 40 races) in the last three Olympic Games (OG): London 2012, Rio 2016 and Tokyo 2021. All results are collected from two databases: Swimrankings (https://www.swimrankings.net/) and World Aquatics (https://www.worldaquatics.com/).

Variables

The main variable used in this research was the athlete's age, expressed in years. This variable was analysed in relation to the criteria of gender, swimming technique, swimming race (i.e. distance), and in relation to the Olympic Games (London 2012, Rio 2016, and Tokyo 2021). Swimming disciplines were analysed in quantitative (absolute) aspect, but also in relation to qualitative aspect (sprint distances - 50 and 100m, middle distance - all 200 and 400 for freestyle; long distances - 800, 1500 and 400 medley). Also, the results were analysed from the aspect of success: Finalists (all swimmers participating in the final races); Medallists (all swimmers who won medals - first three places in the race); Non-medallists (swimmers placed in the final from 4 to 8 places); Gold (all first-place swimmers in the final); Silver (all second-place swimmers in the final); and Bronze (all third-place swimmers in the final).

Statistical analyses

Descriptive statistics were used to determine the basic measures of central tendency (Mean) and measures of dispersion (SD, CV%, Min and Max value, Standard error of mean – S.E.M, absolute and relative value). Differences between ages in relation to gender, technique, discipline, as well as in relation to the Olympic Games were determined by applying MANOVA. The difference between pairs of variables was determined using the ANOVA, and t test with the use of Bonfferoni correction. Effect size (Eta^2) and sample power was calculated, too. Linear regression analysis was used to define the trend of age change as a function of the analysed Olympiads. All analyses were performed by the statistical package SPSS 23.0 (IBM, SPSS statistics, version 23), while the level of statistical probability was set to a p value of 0.05.

Results

Table 1 shows the basic descriptive data of the explored variable as a function of criteria. In summary (for all three Olympiads analyzed, Table 1), the average age of all finalists in men was 24.1 ± 3.6 years, i.e. at the level of the range from 20.5 to 27.6 years (range of MEAN ± SD), while in women it was 23.0 ± 3.7, with a given range of 19.3 to 26.7 years. It was determined that on a general level there is a statistically significant age difference between Olympic male and female swimmers (Wilks' Lambda Value – 0.874, F = 3.704, p = 0.015), and that this difference is responsible for 12.6% of the total variability of the analyzed phenomenon (Eta^2 = 0.126, Observed Power = 0.786).

Table 1. Results of descriptive statistics of the age of top Olympic swimmers in accordance with the explored stratum categories as a function of gender.

	N = M-41; F-40	MEAN	SD	CV (%)	Min	Max	S.E.M (Aps.)	S.E.M (Rel.)
Male	Finalists	24.1	3.6	6.74	17.0	35.0	0.25	0.90
	Medalists	24.1	2.0	8.17	20.3	29.7	0.31	1.04
	No-Medalists	24.0	1.9	7.75	20.4	28.2	0.29	1.03
	Gold	23.6	3.6	15.22	18.0	35.0	0.56	1.60
	Silver	24.3	2. 6	10.54	20.0	31.0	0.40	1.29
	Bronze	24.5	3.8	15.60	17.0	32.0	0.60	1.88
Female	Finalists	23.0	3.7	6.75	15.0	33.0	0.24	0.90
	Medalists	22.7	2.1	9.29	17.7	27.3	0.33	1.21
	No-Medalists	23.1	1.7	7.36	18.6	26.6	0.27	1.02
	Gold	21.7	3.8	17.57	15.0	28.0	0.60	2.14
	Silver	22.6	2.6	11.50	16.0	28.0	0.41	1.46
	Bronze	23.9	3.7	15.28	18.0	33.0	0.58	1.76

Table 2. Results of descriptive statistics of the age of top male Olympic swimmers in relation to disciplines and techniques defined according to the defined stratum categories (Mean ± SD, averaged Min – Max).

Discipline	Finalists	Medalists	No-Medalists	Gold	Silver	Bronze
50 Free	27.0±0.8 (26.3-27.8)	27.9±2.8 (24.7-29.7)	26.4±2.1 (24.2-28.2)	27.0±7.2 (21.0-35.0)	28.3±2.5 (26.0-31.0)	28.3±3.5 (25.0-32.0)
100 Free	22.5±1.0 (21.4-23.4)	24.0±0.9 (23.0-24.7)	21.5±1.2 (20.4-22.8)	22.0±3.6 (18.0-25.0)	24.0±3.6 (21.0-28.0)	26.0±4.4 (21.0-29.0)
200 Free	22.5±1.2 (21.5-23.8)	22.9±2.3 (20.7-25.3)	22.3±1.3 (20.8-23.2)	22.0±2.6 (20.0-25.0)	23.3±1.2 (22.0-24.0)	23.3±3.5 (20.0-27.0)
400 Free	23.2±0.3 (22.9-23.3)	22.5±0.7 (22.0-23.3)	23.5±0.3 (23.2-23.8)	19.7±0.6 (19.0-20.0)	24.3±2.1 (22.0-26.0)	23.7±3.8 (21.0-28.0)
800 Free	24.0±1.6 (22.8-25.1)	23.9±1.2 (23.0-24.7)	24.1±1.8 (22.8-25.4)	22.0±0.2 (22.0-22.4)	26.0±1.4 (25.0-27.0)	23.5±2.1 (22.0-25.0)
1500 Free	23.3±1.1 (22.5-24.5)	23.5±0.4 (23.0-23.7)	23.2±1.6 (21.8-25.0)	21.3±1.2 (20.0-22.0)	24.3±1.2 (23.0-25.0)	24.7±3.1 (22.0-28.0)
100 Back	24.5±0.9 (24.0-25.6)	24.4±0.5 (24.0-25.0)	24.5±1.1 (23.8-25.8)	24.3±3.1 (21.0-27.0)	22.7±2.9 (21.0-26.0)	26.3±4.5 (22.0-31.0)
200 Back	23.1±2.1 (21.9-25.5)	23.4±1.9 (21.3-25.0)	22.9±2.6 (20.6-25.8)	23.0±2.0 (21.0-25.0)	23.7±2.1 (22.0-26.0)	23.7±3.5 (20.0-27.0)
100 Breast	25.4±0.4 (25.1-25.8)	25.5±1.1 (24.7-26.7)	25.6±0.5 (25.2-26.2)	24.3±2.5 (22.0-27.0)	26.7±1.2 (26.0-28.0)	25.3±4.2 (22.0-30.0)
200 Breast	24.4±1.7 (22.6-26.0)	23.1±2.2 (21.0-25.3)	25.1±1.4 (23.6-26.4)	22.0±1.0 (21.0-23.0)	24.0±1.7 (23.0-26.0)	23.3±4.5 (19.0-28.0)
100 Fly	23.5±1.8 (21.5-25.0)	24.2±1.9 (22.0-25.3)	23.1±1.8 (21.2-24.8)	24.3±3.1 (21.0-27.0)	21.7±2.1 (20.0-24.0)	26.7±5.9 (20.0-31.0)
200 Fly	23.9±0.5 (23.4-24.3)	23.1±2.5 (20.3-25.0)	24.3±0.9 (23.4-25.2)	24.0±6.1 (20.0-31.0)	22.7±3.8 (20.0-27.0)	22.7±4.6 (20.0-28.0)
200 Mix	26.0±0.7 (25.1-26.5)	25.9±0.9 (25.0-26.7)	26.0±1.6 (24.2-27.0)	28.3±2.3 (27.0-31.0)	24.3±2.5 (22.0-27.0)	25.0±2.6 (22.0-27.0)
400 Mix	23.3±1.1 (22.4-24.5)	23.3±1.4 (22.0-24.7)	23.3±1.0 (22.6-24.4)	25.3±2.9 (22.0-27.0)	24.7±2.3 (22.0-26.0)	20.0±2.6 (17.0-22.0)

Table 2 shows the basic descriptive data of the explored variable as a function of criteria for male sample. In summary, for all three Olympiads analyzed, the oldest age of all finalists in men was at 50 free (27.0 ± 0.8 years), then it was at 200 Mix and 100 Breast (26.0 ± 0.7, and 25.4 ± 0.4 years, respectively). In general, the youngest swimmers were finalists in the 100 and 200 free (22.5 ± 1.0, and 22.5 ± 1.2, respectively).

Table 4 shows the results of the basic descriptive statistics of the age of top Olympic swimmers with a confidence interval of the mean value in relation to the qualitative aspect of the distance, i.e. sprinters, middle-distance and long-distance swimmers according to gender. The results of the multivariate tests - MANOVA showed that in the general only the age of the tested swimmers in relation to the qualitative criterion of swimming distance is statistically significantly different between the gender at the level of Wilks' Lambda value = 0.886, F = 3.12, p = 0.000, Partial Eta^2 = 0.114 (11.4%), observed Power = 0.704. In relation to the criterion of distance and the cross influence of Gender x Distance, no statistically significant difference was found (Wilks' Lambda value = 0.877 and 0.948, F = 1.65 and 0.657, p = 0.138 and 0.684, Partial Eta^2 = 0.063 (6.3%) and 0.026 (2.6%), observed Power = 0.616 and 0.255, respectively).

Table 3 shows the basic descriptive data of the explored variable as a function of criteria for female sample. In summary, for all three Olympiads analyzed, the oldest age of all finalists in women was, also, at 50 Free (25.9 ± 1.2 years), then it was at 100 Free and 400 Medley (23.8 ± 2.4, and 23.4 ± 2.6 years, respectively). In general, the youngest female swimmers were finalists in the 400 Free (21.6 ± 1.7).

Table 3. Results of descriptive statistics of the age of top female Olympic swimmers in relation to disciplines and techniques defined according to the defined stratum categories (Mean ± SD, averaged Min – Max).

Female	**Finalist**	**Medalis**	**No-Medalist**	**Gold**	**Silver**	**Bronze**
50 Free	25.9±1.2 (24.5-26.8)	26.1±1.6 (24.3-27.3)	25.7±1.0 (24.6-26.4)	23.3±3.2 (21.0-27.0)	24.7±4.2 (20.0-28.0)	30.3±3.1 (27.0-33.0)
100 Free	23.8±2.4 (22.4-26.6)	22.8±3.6 (19.7-26.7)	24.5±2.0 (22.6-26.6)	21.3±5.5 (16.0-27.0)	23.3±3.1 (20.0-26.0)	23.7±5.0 (19.0-29.0)
200 free	22.9±0.9 (22.0-23.8)	21.9±0.5 (21.3-22.3)	23.4±1.5 (21.8-24.8)	20.7±1.5 (19.0-22.0)	23.0±1.0 (22.0-24.0)	22.0±1.0 (21.0-23.0)
400 Free	21.6±1.7 (19.6-22.6)	21.9±0.5 (21.3-22.3)	21.5±2.5 (18.6-23.0)	20.7±1.5 (19.0-22.0)	24.0±2.0 (22.0-26.0)	21.0±2.0 (19.0-23.0)
800 Free	22.3±1.1 (21.4-23.4)	21.7±1.7 (19.7-22.7)	22.6±1.3 (21.4-24.0)	19.3±4.5 (15.0-24.0)	22.7±2.9 (21.0-26.0)	23.0±0.0 (23.0-23.0)
1500 Free	22.8±2.6 (19.0-27.0)	24.0±3.0 (21.0-27.0)	22.0±2.2 (10.0-25.0)	24.0	21.0	27.0
100 Back	21.9±1.0 (21.0-22.9)	21.5±0.4 (21.3-22.0)	22.1±1.6 (20.8-23.8)	21.3±5.1 (17.0-27.0)	21.3±3.2 (19.0-25.0)	22.0±4.4 (19.0-27.0)
200 Back	22.3±1.3 (21.4-23.8)	23.0±3.1 (19.3-25.0)	21.9±1.5 (20.2-23.0)	20.0±3.0 (17.0-23.0)	24.3±2.5 (22.0-27.0)	24.3±5.0 (19.0-29.0)
100 Breast	22.6±0.9 (21.6-23.3)	21.6±1.2 (20.3-22.7)	23.2±0.7 (22.4-23.6)	17.0±2.0 (15.0-19.0)	24.3±0.6 (24.0-25.0)	23.3±2.1 (21.0-25.0)
200 Breast	23.3±0.4 (23.0-23.8)	24.0±1.7 (22.0-25.0)	22.9±0.8 (22.0-23.6)	25.7±2.1 (24.0-28.0)	23.0±1.7 (21.0-24.0)	23.3±3.5 (20.0-27.0)
100 Fly	22.6±0.5 (22.1-23.2)	23.4±0.6 (22.7-23.7)	22.1±0.8 (21.2-23.2)	22.7±1.5 (21.0-24.0)	20.7±4.0 (16.0-23.0)	26.7±2.5 (24.0-29.0)
200 Fly	23.0±1.7 (21.5-24.9)	22.7±1.8 (20.7-24.3)	23.3±2.4 (21.8-26.0)	23.0±3.0 (20.0-26.0)	20.3±1.2 (19.0-21.0)	24.7±3.2 (21.0-27.0)
200 Medley	22.9±0.5 (22.6-23.5)	22.0±1.7 (20.3-23.7)	23.5±0.5 (23.0-24.0)	23.0±6.1 (16.0-27.0)	21.7±2.1 (20.0-24.0)	21.3±1.5 (20.0-23.0)
400 Medley	23.4±2.6 (20.5-25.5)	22.4±4.1 (17.7-25.3)	23.9±2.1 (22.2-26.2)	23.0±6.1 (16.0-27.0)	20.7±2.1 (19.0-23.0)	23.7±4.9 (18.0-27.0)

Table 4. Results of the basic descriptive statistics of the age of top Olympic swimmers in relation to sprinters, middle distance and long distance swimmers as a function of gender with established ANOVA differences.

Dependent Variable	Gender	Distance	Age	95% Confidence Interval		ANOVA – Tests of Between-Subjects Effects; F value; p significance; partial Eta^2		
				Lower Bound	Upper Bound	Gender	Distance	G x D
Medal winners	Female	Sprint	23.1	22.0	24.1	F = 8.73; p = 0.004; Eta^2 = 10.4%	F = 3.14; p = 0.049; Eta^2 = 7.8%	F = 3.08; p = 0.466; Eta^2 = 2.0%
		Middle	22.6	21.6	23.5			
		Long	22.3	20.8	23.8			
	Male	Sprint	25.2	24.2	26.2			
		Middle	23.5	22.5	24.4			
		Long	23.5	22.1	24.9			
Other finalists	Female	Sprint	23.5	22.6	24.4	F = 3.39; p = 0.070; Eta^2 = 4.3%	F = 0.85; p = 0.431; Eta^2 = 2.2%	F = 1.34; p = 0.664; Eta^2 = 1.1%
		Middle	22.7	21.9	23.6			
		Long	23.1	21.7	24.4			
	Male	Sprint	24.2	23.3	25.2			
		Middle	24.0	23.2	24.9			
		Long	23.5	22.2	24.7			
Finalists	Female	Sprint	23.4	22.5	24.2	F = 7.45; p = 0.008; Eta^2 = 9.0%	F = 2.25; p = 0.113; Eta^2 = 5.6%	F = 0.46; p = 0.833; Eta^2 = 0.5%
		Middle	22.7	21.9	23.4			
		Long	22.8	21.6	24.0			
	Male	Sprint	24.6	23.8	25.4			
		Middle	23.8	23.1	24.6			
		Long	23.5	22.4	24.6			

Figures 1 and 2 show the results of the trend of change in the average age of top Olympic swimmers in relation to the analyzed Olympic Games. Figure 3 shows the results of the overall average age of top Olympic swimmers as a function of swimming strokes for all analyzed Olympic games.

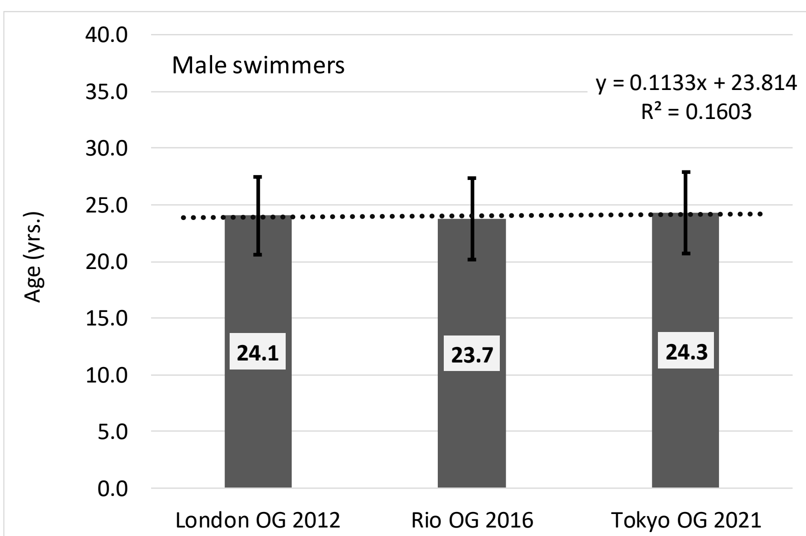

Figure 1. The average age of finalist male swimmers in the last three Olympics with the defined change trend equation.

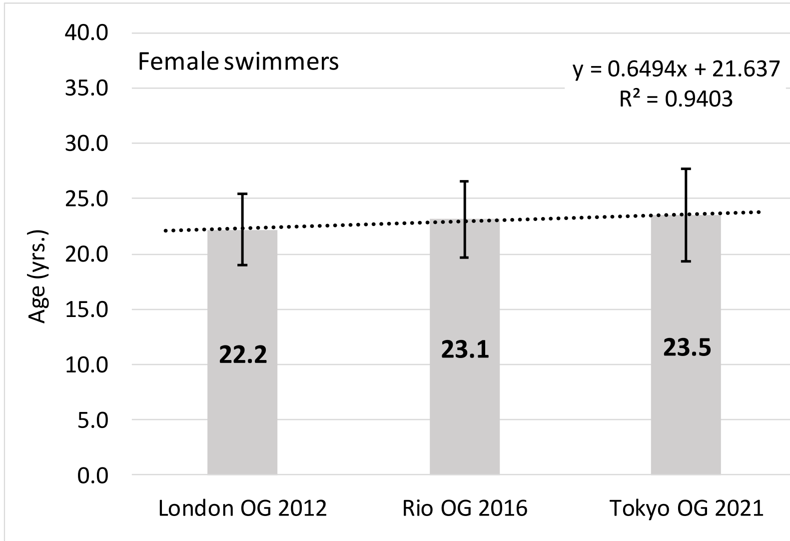

Figure 2. The average age of finalist female swimmers at the last three Olympics with the defined change trend equation.

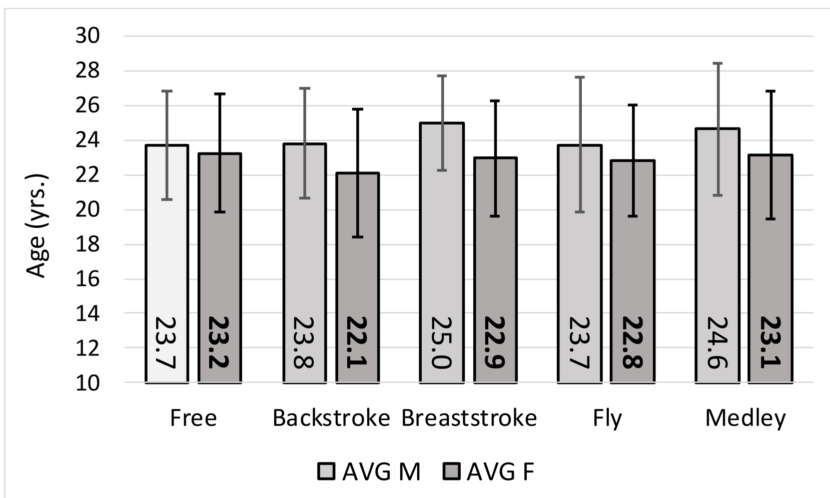

Figure 3. The average age of elite Olympic swimmers according to stoke and gender.

Discussion

Swimming, as one of the oldest sports in human history, is a constant subject of scientific research (Lohn, 2021). One of the most common research phenomena in sports, in a general, and also in swimming as an individual sport, is the age of swimmers at which top results are achieved (Okičić et al., 2007; Đurović et al., 2020; Mallett et al., 2021; Gorzi et al., 2022).

The results showed that the Olympic elite male swimmers, on average, were statistically significantly older than Olympic elite female swimmers (Wilks' Lambda Value – 0.874, F = 3.704, p = 0.015) by 1.1 years, or 4.8% (Table 1). Generally observed (OG 2012, 2016 and 2021) in relation to the of success (medal winners' vs other finalists), the age of between gender - male and female swimmers, is statistically significantly different: medal winners' F = 9.56, p = 0.003 (Eta^2 = 0.108, Observed Power = 0.863), as well as other finalists' F = 5.15, p = 0.026 (Eta^2 = 0.061, Observed Power = 0.611). In other words, the male medal winners are statistically significantly older than the female medal winners (Males: Medal-winning swimmers – 24.1 ± 2.0 years, i.e. at the level of the range from 22.1 to 26.1 years on average; Females: medalist swimmers - 22.7 ± 2.1 years, i.e. at the level of the range from 20.6 to 24.8 years on average), just as the other male finalists are statistically significantly older than the other female finalists (Males: No-Medalist finalist swimmers - 24.0 ± 1.9 years, i.e. at the level of the range from 22.1 to 25.9 years on average; Females: finalist swimmers - 23.1 ± 1.7 years, i.e. at the level of the range from 21.4 to 24.8 years on average).

A slightly higher influence of the difference between the sexes in medalists compared to No-Medalists (Eta^2 = 10.8 vs 6.1%), may indicate the possible fact of a higher influence of chronological age (chronological maturity) in male competition on winning medals at the Olympic Games, compared to female competition. This possible claim is accompanied by the fact of a quantitatively greater age difference between the medal winners between the sexes (1.4 years, and 5.81%) compared to the mentioned values of the differences between all finalists (1.1 years, i.e. 4.8%).

The results of the differences in relation to the distance (sprinters, 50 and 100m; middle-distance, 200 and 400m; and long-distance, 800, 1500m and 400 mix) showed that a statistically significant difference between the sexes was found in medal winners as a function of swimming distance ($F = 8.73$, $p = 0.004$, $Eta^2 = 10.4\%$), but that difference also exists between distances ($F = 3.14$, $p = 0.049$, $Eta^2 = 7.8\%$, Table 4). In other words, the age of sprinters, middle-distance and long-distance differs between male and female swimmers, and the age of sprinters, middle-distance and long-distance swimmers also differs in general. The results showed that sprinters are statistically significantly older ($p = 0.049$) than middle and long-distance swimmers whose ages do not differ from each other. From a practical point of view, among medal winners, sprinters are on average the oldest individuals in elite Olympic swimming regardless of gender, and this is especially true for the distance of 50m freestyle (male medalists 27.9±2.8, female medalists 26.1±1.6 yrs., Table 2 and 3).

In relation to the overall average age results (Table 1), it can be concluded that the Gold medalists are the youngest of all other strata of elite Olympic swimmers (Males - 23.6±3.6, Females - 21.7±3.8 yrs.). This fact is most likely an indication that training in relation to extremely talented swimmers, regardless of gender, is primarily directed towards achieving the maximum competitive result, i.e. the Olympic gold medal. It is obvious that regardless of the swimmer's chronological age, the training process is directed to the given result potential as a priority goal in working with the mentioned extremely talented swimmers.

In relation to the type of distance, the results showed that, in general, long-distance swimmers are the youngest, followed by middle-distance swimmers and sprinters (Table 4). Considering stoke (Figure 3) among male swimmers, breaststrokers and mix are on average the oldest (25.0 and 24.6 yrs.), while the youngest are free and fly swimmers (23.7 yrs.). Among female swimmers the oldest are free and mix (23.2 and 32.1 yrs.), while the youngest are breaststrokers (22.1 yrs., Figure 3).

By the calculated regression equations, it can be argued at a hypothetical level that the average age of swimmers at the next Olympic Games in Paris in 2024 will be 24.3 years, but that the average age of female swimmers will be 24.2 years (almost equal to male swimmers). Based on these hypothetical assumptions, it is possible that at the Olympic Games in Paris, the age of male and female swimmers will become equal on average for the first time in history, which will certainly be the subject of verification and research in the future as well.

The results of this study agree with the general data on the age of top athletes from various sports and, it can be argued that in relation to the established results (as a researched phenomenon) they are directly related to the biological basis of human morphology, psychology and physiology in relation to the potential to achieve top sports results (Wylleman & Reints, 2010; Allen & Hopkins, 2015; Đurović et al., 2020). Namely, previous systematic public research has shown that there is a significant relationship between the age of peak career performance and the type of physical effort such as explosive power or sprinting disciplines, in relation to endurance disciplines. In the disciplines dominated by explosive power or sprinting, the peak of results occurred in the range of about 27 years (1-20 sec), while with the increase in the duration of the race, the age decreased to about 20 years (21- 245 s). Also, a small difference in peak age estimates for these types of competitive events was found between men and women (Allen & Hopkins, 2015).

In previous research, it was established that the biological peak of the muscle component in the body is found at the age of about 25 to 35 years, regardless of gender (Dopsaj et al., 2020[a]). In other words, at a given age, human beings have the biggest biological potential for achieving the maximal level of manifestation of strength or power characteristics. Also, it was determined that, in relation to body composition, the result of sprint swimming is associated with 35.1 and 75.1% in male and female swimmers, respectively, with optimal representation of contractile (muscle) tissue (Dopsaj et al., 2020[b]). This means that the result in sprint disciplines for female swimmers depends more on the muscular component in the body compared to male swimmers, which in female swimmers may also represent the basis of the biological potential of the tendency to reach the peak results at an older age than was the case in previous Olympics.

Of course, factors such as experience, motivation, training conditions, control and method of supplementation, recovery methods, quality of supplementary training (dry and gym), social and material status of living conditions have a very significant influence on the duration of the career, i.e. on Age-peak performance relationship (Wylleman & Reints, 2010; Đurović et al., 2020; Dopsaj et al., 2023).

Practical Implications

The results showed that the average age of elite male and female swimmers who were finalists at the last three Olympiads was 24.1 ± 3.6 years, and for women it was 23.0 ± 3.7 years, respectively. The age of elite Olympic male and female swimmers is statistically significantly different. In relation to the qualitative aspect of the characteristics of swimming distances, i.e. sprinters, middle distance and long distance swimmers according to gender, it was found that sprinters are statistically significantly older, regardless of gender, while no difference was found between middle and long distance swimmers. It should be noted that long distance swimmers are generally at youngest age. Among medal winners, sprinters are on average the oldest individuals in elite Olympic swimming regardless of gender, especially at the distance of 50m freestyle (male medalists 27.9±2.8, female medalists 26.1±1.6 yrs.).

Considering stroke, among male swimmers, breaststrokers and mix are on average the oldest one (25.0 and 24.6 yrs.), while the youngest are free and fly swimmers (23.7 yrs.). Among female swimmers the oldest are free and mix (23.2 and 23.1 yrs.), while the youngest are breaststrokers (22.1 yrs.).

The results of regression equations, showed that, at a hypothetical level, the average age of swimmers at the next Olympic Games in Paris in 2024 will be 24.3 years, but that the average age of female swimmers will be 24.2 years (almost equal to male swimmers).

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Original article

Eating Behavior and Body Composition Analysis of Active College Students: A Cross-Cultural Perspective between Lebanon and Foreign countries

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Abstract

This study aims to examine and compare the Nutrition Habits and body composition among Lebanese universities' active students according to gender characteristics, as well as to explore the effect of these Nutrition habits on body composition parameters. A sample of 200 students (100 males, 100 females) from the Lebanese University, faculty of education were studied. The standardized self-administered dietary questionnaire (Turconi et al., 2003) was used to assess the students' Nutrition habits. In addition, the method of multi-frequency bioelectrical analysis was used to assess five Body Composition parameters: (BH), (BM), (BMI), (PBFM), and (PSMM). Regarding Nutrition Habits, the Lebanese students showed satisfactory results and scored above average in all sections of the nutrition survey. The Frequency of food consumption showed that only (32%) of the students reported skipping fast food consumption, while (16.5%) of them reported skipping sweet consumption. Daily consumption of 2 portions or 200 g of Fruits and Vegetables was reported by (30.5% and 50%) of the students respectively. As for body composition, both male and female students were found in normal body weight (Males: BMI=23.12, and PBFM=12.0), and (Females: BMI=20.9, and PBFM=22.2). In addition, the Pearson correlation analysis that discovered multiple relations between the body composition measures and dietary habits determined low to moderate negative and positive significant correlations. Therefore, Nutrition Habits could predict body composition in Lebanese college students. Lebanese students might benefit from college nutrition educational programs to translate theoretical nutritional knowledge into a practical daily-life eating pattern.

Keywords: University students, Lifestyle, Nutrition Habits, Health

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Introduction

Diet and exercise have a big impact on weight management, fitness, health, and preventing chronic diseases (Kljajevic et al., 2021). Consuming more energy than required leads to the formation of fat, which is the cause of obesity. Eating only enough to maintain daily energy output might result in an unaltered accumulation of fat, injury to the body and mind, and a shorter life span (James, 2004). Due to obstacles including time management problems, stress from studies, environmental adjustment, and hectic schedules, young adults attending college tend to be less attentive to their health. According to Ganasegeran et al., (2012), they indulge in unhealthy behaviors such as smoking, eating fast food, skipping meals, and using the internet excessively. Sedentary behaviors like sitting, watching TV, and using computers have also been linked to weight growth and obesity (Ganasegeran et al., 2012; Meyer et al., 2008).

Body composition analysis is a sensitive component in biological understanding and an essential screening technique for managing nutritional and health status. It also indicates changes in health. (1992, Wang et al.; 2000, Ellis). According to Wang et al. (2004), "body cell mass serves as a biomarker of these processes and is altered by nutritional status, physical activity level, and disease state" (Wang et al., 1992; Wang et al., 2004; Ellis, 2000). Over time, poor eating habits have become more common among Arab adults and children (Rahim et al., 2014). Over the last few years, fast food has replaced the traditional Mediterranean diet as the main source of nourishment in Lebanon. As a result, the number of overweight and obese youth is rising (FAO, 2010).

Research from around the globe indicates that smoking, eating poorly, and not getting enough exercise are the three main health issues that college students face (Irwin, 2004; Steptoe et al., 2002). Studies (Deliens et al., 2015; Vella-Zarb et al., 2009; Yahia et al., 2016; Martins et al., 2021) have reported a significant prevalence of overweight in university settings. As far as we are aware, there are only two Lebanese research on university students who do not participate in sports that found that most of them had normal weights but poor eating habits (Assaf et al., 2019; Yahia et al., 2008).

Based on the aforementioned information, it can be said that a study is required to determine the profiles of dietary habits and body composition among active Lebanese university students and investigate the impact of dietary habits on body composition parameters based on gender characteristics. Dietary habits may be an independent variable that statistically significantly influences Lebanese university students' body composition quality. Knowing the dietary habits and body composition profiles of active university students in Lebanon is important for promoting overall health and well-being in this population. The study intends to better understand the dietary habits and body composition profiles of active university students in Lebanon to inform interventions and instructional initiatives aimed at enhancing physical fitness and nutritional habits.

Methods

Design of the study

This study is a cross-sectional descriptive study of a deductive quantitative research approach.

Participants

The study sample comprised two hundred (200) physically fit students, with a mean age of 22.1± 4.1 years. Of them, 100 were male and 100 were female. Both the anthropometric measurements and the online survey have been completed by all participants. They were selected from the Lebanese university's faculty of education, physical education department, and sports major. The participants had to be of college age and enrolled full-time in the three-year bachelor's degree programme in order to be eligible for participation. One was excluded if they were unable to participate in body composition assessments due to a significant accident, chronic disease, or handicap. The student affairs office assistant randomly selected students from the physical education and sports classes.

Measurements and Procedures

To get pertinent data, two procedures were used. Students were required to perform the anthropometric and body composition measurements after completing the Eating Habits questionnaire.

Step 1: The study assessed eating behaviors using a self-reported questionnaire (Turconi et al., 2003), with an emphasis on food consumption frequency, Eating habits, physical activity, dietary beliefs, and nutrition knowledge. Secrecy and anonymity were guaranteed by using Google Forms to administer the questionnaire. With statistically significant Pearson correlation coefficients and Cronbach's alpha ranging from 0.55 to 0.75, the results demonstrated adequate reliability.

Step 2- Following the completion of questionnaires, the InBody 270 analyzer (Biospace Co. Ltd., Seoul, Korea) was used to measure the following aspects of body composition: body height, weight, body mass index, percentage of body fat mass, and percentage of skeletal muscle mass. To ensure accuracy, participants stayed off meals and liquids for at least three hours before taking their measures while standing on a scale with only their hands and feet. Each subject's body mass was measured to the closest 0.1 kg while they were wearing light clothing. Standing height barefoot was measured using a wall-mounted stadiometer, which was accurate to within 0.5 cm. By responding to the first question on the questionnaire, participants submitted a consent form that verified their participation in the study.

Additionally, students were given the assurance that the data collected would be kept private and utilized only for scientific research. The information was gathered in 2021. The research protocol was authorized by the University of Belgrade's Faculty of Sports and Physical Education's Ethical Committee under the number 484–2 and was acknowledged in the Declaration of Helsinki (World Medical Association, 2013).

Statistical analyses

All of the statistical analyses were carried out using IBM's Statistical Package for the Social Sciences (SPSS, version 25). A significance level of $p < 0.05$ has been established. In descriptive statistics, the measures of central tendency and variability were presented by the mean, standard deviation (SD), minimum, maximum (max), and coefficient of variation (cV%). In addition, the inferential statistics included the Mann-Whitney U test, Pearson correlation, and the Chi-square analysis to determine the relations, significant differences, and predictions among the variables of both nutrition habits and body composition parameters of the Lebanese students.

Results

Anthropometric Measurements

As expected, male students tended to be heavier and taller than female students (Table 1 and 2). Male students had higher values for most BC parameters, contributing to their higher total body mass. The one exception is that women's body fat percentage is higher than men's (22.2% vs. 12.0%). Even enough the mean body fat percentage of women was higher than that of men, both genders' values were within the permissible range (10–20% for men and 18–28% for women) (InBody, 2018).

Table 1. Descriptive Statistics for male PE and Sport students.

Variable	Mean	SD	Min	Max	cV (%)
Age	21.5	2.9	18.0	38.0	13.3
BH (cm)	177.0	0.07	159.0	199.0	3.8
BM (kg)	72.8	10.2	52.9	102.2	13.7
BMI	23.12	2.4	18.6	29.3	10.4
PBFM (%)	12.0	4.3	5.0	23.6	35.6
PSMM (%)	47.7	6.7	26.9	68.8	12.7

Table 2. Descriptive Statistics for female PE and Sport students.

Variable	Mean	SD	Min	Max	cV (%)
Age	21.8	4.1	18	41	18.9
BH (m)	164	0.06	152	177	3.4
BM (kg)	56.4	7.0	42.3	73	12.5
BMI	20.9	2.3	15.9	27.7	10.9
PBFM (%)	22.2	5.8	11	35.4	27.6
PSMM (%)	33.3	3.4	25.5	42.0	8.1

Nutrition Habits

Regarding the Nutritional Habits assessment presented in Table (3), both genders received satisfactory results in the first section of the Nutrition Survey (Dietary Habits), with no significant difference in the mean of the section score (p=.228), according to the Mann-Whitney U Test, which examined the mean scores of the Nutrition Survey sections for both genders. While girls were better at consuming vegetables than boys, with 62% to 38% of them reporting regular intake, almost one-third of the students reported frequently taking at least two servings of fruits daily (27% of males and 34% of females). Students of both genders occasionally ingested cakes and sweets during meals (56% vs. 57%, respectively). 51% of the males and 59% of the females reported eating three meals a day regularly.

In regards to the results of the Physical Activity section, the gender-based classification indicated that students of both genders were equally active, with male students (n = 100) scoring a mean of 16 and female students (n = 100) scoring a mean of 16.2 (p=.519). In comparison, 49% and 24% of female students assessed their lifestyle as moderately active to very active, whereas around one-third of male students (28% and 34%) described it as moderately active to very active.

Students demonstrated an adequate understanding of what a healthy diet entailed in the Dietary Beliefs section, with a statistically significant difference (p=.031) between female students and male students. The mean score for females was 8.9 for males and 9.3 for females out of a total score of 12. In both sample groups, students answered the three questions about what constitutes a healthy diet accurately.

Table 3. Mean Scores of the Nutrition Survey sections by Gender- Mann-Whitney U Test

	Questionnaire Section	Scores	Males (100)	Females (100)	p value
1	Dietary Habits Total Score 52	Lowest	22.8	21.3	
		Mean	**35.8**	**35.1**	**.228**
		Highest	47	44.6	
2	Physical Activity and Lifestyle- Total Score 24	Lowest	9.0	11.5	
		Mean	**16**	**16.2**	**.519**
		Highest	19	18.1	
3	Dietary beliefs Total Score 12	Lowest	7.0	8.3	
		Mean	**8.9**	**9.3**	**.031**
		Highest	10	11.1	
4	Nutrition Knowledge Total Score 11	Lowest	5.4	2.0	
		Mean	**6.7**	**6.3**	**.016**
		Highest	9.0	10.1	

In the nutritional knowledge section, the mean score for males and females was 6.7 and 6.3 respectively, on a total score of 11. When it came to questions about foods high in dietary fiber, foods low in fat, foods high in protein, various food substances containing energy, the roles of vitamins and minerals, and the "definition" of daily energy expenditure, men reported having a better understanding of nutrition with clear significant difference (p=.016).

Chi-square for Physical Activity and Nutrition variables

The Chi-square technique found significant differences between the expected and observed numbers of students in the nutrition variables including questions of section (B - Frequency of food consumption) (Table 4). Regarding nutrition variables, the frequency of healthy food consumption by Lebanese university students was found below the 4^{th} percentile in all the 12 variables.

Table 4. Chi-square –Nutrition Variables: Section B – Frequency of Food Consumption.

Variable	Healthiest option	Expected (N)	Observed (N-%)	p value
Eating Habits				
Meat/Week	1-2 times/week	200	15 (7.5%)	0.000
Fish/Week	1-2 times/week	200	11 (5.5%)	0.000
eggs/Week	1-2 times/week	200	69 (34%)	0.000
Cheese/Week	More than 4 times/week	200	91 (45.5%)	0.000
Ham,Salami,Sausags /Week	Never	200	6 (3%)	0.000
Legumes/Week	More than 4 times/week	200	133 (66.5%)	0.000
Fruits/Day	at least 2 portions or (200g)	200	61 (30.5)	0.000
Veggies/Day	at least 2 portions or (200g)	200	100 (50%)	0.000
Sweets/Week	Never	200	33 (16.5%)	0.000
Fried Potato/Week	Never	200	3 (1.5%)	0.000
Fast Food/Week	Never	200	64 (32%)	0.000
Pizzeria/Week	Never	200	9 (4.5%)	0.000

Pearson Correlation Analysis for Body Composition and Nutrition Habits

In addition, the Pearson correlation analyses that discovered multiple relations between the body composition measures and dietary habits presented in tables (5, 6, 7, and 8) determined low to moderate negative and positive significant correlations between variables of the two lifestyle factors. The greatest influence on body composition represented by their correlations with Dietary habits variables among the two students' samples were as follows:

In the male sample (Tables 5, and 6): Consuming pizzeria per week showed low positive and negative influence on PBFM and PSMM. Moreover, Eating Breakfast showed same the correlation level with BM, BMI, and PSMM.

Table 5. Pearson Correlation Coefficients for Body Composition indices and Weekly Frequency of Food consumption indices in male sample group

Variable	Meat	Fish	Eggs	Cheese	Ham, Salami, Sausages	Legumes	Sweets	Fried Potato	Fast Food	Pizzeria
BW	-0.104	0.108	-0.018	0.033	0.051	-0.002	-0.122	0.007	0.115	0.186
BH	-0.114	0.157	0.001	-0.035	0.106	0.114	0.020	0.041	0.078	0.082
BMI	-0.046	0.040	-0.019	0.071	0.000	-0.096	-0.180	-0.024	0.099	0.193
PBFM	-0.060	0.005	-0.038	0.084	0.065	-0.098	-0.113	-0.107	0.062	**.288****
PSMM	0.026	0.015	0.040	0.063	0.059	0.114	0.117	0.148	-0.125	**-.226***

Note: r (Pearson correlation coefficient). * p < 0.05; ** p < 0.01.

Table 6. Pearson Correlation Coefficients for Body Composition indices and Dietary Habits indices in male sample group.

Variable	BW	BH	BMI	PBFM	PSMM
Eating Breakfast	**-.200***	0.006	**-.261****	-0.180	**.273****
Beverages at Breakfast	-0.015	0.070	0.017	0.135	0.164
Breakfast Content	0.044	-0.031	-0.084	0.041	0.016
Fruits/Day	0.136	0.170	0.065	-0.022	-0.053
Veggies/Day	0.010	0.024	-0.013	-0.133	0.101
Cake/dessert at meals	0.026	0.141	-0.076	-0.109	**.220***
Three meals daily	-0.163	-0.013	**-.200***	-0.143	**.226***
Diet type	0.057	-0.099	-0.001	-0.053	-0.047
Diet content	-0.094	-0.186	0.009	-0.118	-0.094
Snacks content	0.169	0.024	0.193	-0.098	-0.034
Beverages between meals	-0.052	-0.036	-0.036	0.135	-0.132
Milk or yogurt/day	0.030	0.078	-0.014	0.049	0.007
Mineral water/day	0.011	**.239***	-0.165	**-.221***	-0.148

Note: r (Pearson correlation coefficient). * p < 0.05; ** p < 0.01.

Table 7. Pearson Correlation Coefficients for Body Composition indices and Weekly Frequency of Food consumption indices in female sample group.

Variable	Meat	Fish	Eggs	Cheese	Ham, Salami, Sausages	Legumes	Sweets	Fried Potato	Fast Food	Pizzeria
BW	0.007	**.238***	0.177	-0.021	-0.032	-0.163	**.246***	0.005	0.005	-0.159
BH	**.219***	0.091	**.361****	**.227***	**.266****	0.031	0.029	**.198***	-0.149	-0.179
BMI	-0.128	**.221***	-0.022	-0.157	**-.198***	**-.205***	**.279****	-0.131	0.101	-0.053
PBFM	-0.034	**.210***	0.132	-0.102	-0.100	-0.171	**.335****	-0.046	0.094	-0.007
PSMM	0.012	-0.190	-0.140	-0.007	0.151	0.078	**-.312****	0.064	**-.273****	0.107

Note: r (Pearson correlation coefficient). * p < 0.05; ** p < 0.01.

Table 8. Pearson Correlation Coefficients for Body Composition indices and Dietary Habits indices in female sample group.

Variable	BW	BH	BMI	PBFM	PSMM
Eating Breakfast	0.072	0.015	0.070	-0.044	-0.130
Beverages at Breakfast	**-.412****	0.124	**-.381****	**-.344****	0.184
Breakfast Content	**-.274****	0.070	-0.072	-0.188	**.199***
Fruits/Day	0.056	**.203***	-0.045	-0.025	-0.060
Veggies/Day	-0.120	**.289****	**-.318****	**-.242***	**.328****
Cake/dessert at meals	**.215***	-0.086	**.308****	**.221***	**-.236***
Three meals daily	-0.014	0.060	-0.059	0.025	-0.122
Diet type	-0.173	-0.116	-0.129	-0.090	0.087
Diet content	**.266****	0.071	0.037	0.077	-0.126
Snacks content	0.044	-0.030	0.064	-0.038	0.111
Beverages between meals	-0.104	-0.140	-0.026	.068	0.118
Milk or yogurt/day	0.169	0.054	0.065	0.106	-0.105
Mineral water/day	0.148	0.131	0.090	0.178	-0.089

Note: r (Pearson correlation coefficient). * p < 0.05; ** p < 0.01.

In the female sample (Tables 7, and 8): Consuming sweets per week showed a (low positive and negative influence on BM, BMI, PBF, and PSMM. In addition, Beverages at breakfast displayed (low to moderate positive and negative influence on BM, BMI, and PBFM.

Therefore, dietary habits variables carried a significant low to moderate positive and negative effect on most body composition indices among both Lebanese student samples. To summarize, the Pearson correlation analysis has found significant (Low to moderate) correlations between the Nutrition habits and body composition of the Lebanese students and therefore, Nutrition Habits could predict body composition in this sample.

Discussion

The purpose of the study is to examine and compare the Nutrition Habits and body composition among Lebanese universities' active students according to gender characteristics, as well as to explore the effect of these Nutrition habits on body composition parameters. In terms of body composition, women's body fat mass percentage was found to be higher than men's, while it was still within the healthy range recommended by InBody (2018). The demand for "thinness" in academic contexts and women's increased self-consciousness about their weight and body type may be the causes of this (Sheldon et al., 2010; Ferguson et al., 2011).

The National Heart, Lung, and Blood Institute (1998), states that the BMI levels for both samples were within the normal range of 18.50–24.99 kg/m2. Male BMI values were higher than female BMI values. Overweight or obese students are more likely to stay that way as they get older (National Research Council and Institute of Medicine, 2013; Strong et al., 2008). Male students from Madrid (Spain), Valencia (Spain), Valparaíso (Chile), and Valencia (Spain) had the lowest averages in terms of PBFM, with male students from Lebanon having higher averages (12%) than those from Poland (Gdansk) and Spain (Murcia) (Lopez Sanchez et al., 2019). Additionally, Dopsaj et al. (2015) reported that the average BMI of female students at the University of Belgrade in Serbia was similar to that of Lebanese students (20.9 kg/m2). Furthermore, the percentage of skeletal muscle mass (PSMM) in the Lebanese male student sample group was suitable (47.7%), and considered higher than the percentage of male Abu Dhabi police officers (42.2%).

Results regarding dietary habits revealed that students of both genders get satisfactory outcomes. The four sections of the dietary habits survey (Turconi et al., 2003) nutritional knowledge, dietary beliefs, physical activity and lifestyle, and dietary habits, showed mean scores higher than averages in each category. The survey was given to samples of both students. Comparing American university students to Lebanese students, Yahia et al. (2016) showed that American students had superior physical activity, dietary beliefs, and nutritional knowledge. The Lebanese and American male students received comparable average percentages (68.8% and 67.3%) in the Dietary Habits section. On average, American female students scored higher (71.1%) than their counterparts from Lebanon (67.5%) in the nutrition habits section. The average percentages for American male students (76%), and female students (70%), in the Physical Activity part were higher than the scores for Lebanese students (66.7% and 67.5%, respectively). Male students from Lebanon and the United States got comparable average percentages (74.7% and 74.2%, respectively) in the Dietary Beliefs section. On the other hand, the average percentage of American female students (82%) was higher than that of Lebanese female students (77.5%). The nutrition knowledge section was the last one in the nutrition survey. American students scored (68.8%) and (63.8%) for males and females, respectively, while Lebanese students had lower average percentages for both genders (60.9%) and (57.3%).

According to the study, at least two servings of fruit are consumed every day by Lebanese students—27% of male students and 34% of female students. This is less than the findings of a study conducted by Yehia et al. (2016), which showed that over half of American students—especially female students consume at least two servings of fruits per day. Obesity is linked to low fruit and vegetable consumption (Lin & Morrison, 2002; Cho et al., 2003; Tohill et al., 2004). The percentage of students who ate breakfast every day (53%) in the study by Yahia et al. (2016) was less than that of the Lebanese sample students (63%). In contrast, the percentages of Lebanese and American university students who reported eating breakfast every day (89.3%) were lower than those of their Canadian university counterparts (2010). Breakfast consumption reduces the amount of fat in the diet and reduces the amount of impulsive snacking (Schlundt et al., 1992; Yahia et al., 2008).

About half of the Lebanese students (51% of the males and 59% of the females) reported eating three meals a day regularly. About this criterion, the results were better than those of the American pupils (43% males and 38% females). Males demonstrated significant disparities in their food patterns from females when it came to daily water consumption of at least 1-1.5 L. Women demonstrated (66%) and men demonstrated (81%) with a statistically significant difference between the sexes (p=.019). There was a significant gender difference in the daily water consumption as compared to the results of (Yahia et al., 2016) on this dietary habits variable. More men than women reported consuming at least 1-2 L of water per day (p=.001).

The results of the Physical Activity and Lifestyle section showed that the Lebanese students had a very physically active lifestyle. Furthermore, this section's gender-based classification demonstrated that both genders were equally engaged. In terms of the classification based on gender, the majority of male students (79%) and nearly all female students (99%) stated that they engaged in physical exercise for the entire year; more than four hours per week were reported by 78% of male students and 62% of female students. In comparison, 49% and 24% of female students assessed their lifestyle as moderately active to very active, whereas around one-third of male students (28% and 34%) described it as moderately active to very active. When compared to Central Michigan University's American student body, half of the American students reported engaging in physical activity, but only approximately one-third (33%) of the students said they exercised for more than four hours each week. Compared to females, males were more active.

The findings in the Dietary Beliefs section showed that students, particularly female students, had a sufficient understanding of what a healthy diet entail. These findings support previous research (Turconi et al., 2008; Croll et al., 2001) and imply that students' understanding of what constitutes a healthy and harmful diet complies with dietary recommendations (Dietary Guidelines Advisory Committee, 2010). Lebanese students were found to have enough nutritional knowledge in the last section of the Turconi et al. (2003) questionnaire. However, male students reported having greater understanding in areas such as energy, dietary fibers, vitamins, minerals, and energy expenditure. The results of Yahia et al., (2016), and Von Bothmer & Fridlund, (2005) who discovered that female students had a higher nutritional knowledge score than male students are contrasted with this section's results depending on gender. In general, women are more likely than men to be motivated to make healthy changes, manage their weight, and pay attention to nutrition (Von Bothmer & Fridlund, 2005; Livingston et al., 2012).

The non-parametric Chi-square test used to determine expected and observed results in healthy eating habits of the Lebanese students' sample has demonstrated the following general result: the healthiest eating habits (Mediterranean food) determined in "Krause's food, nutrition, and diet therapy textbook" authored by Kathleen, Mahan, and Stump (2004), were reported by less than one-third of the Lebanese students' sample (n=200). These results were found poor when compared to other relevant American and Canadian studies assessing similar nutrition variables (Yahia et al., 2016; Lachance et al., 2010). Yahia et al. (2016) study found for instance that fast food consumption was prohibited by 33% of Central Michigan University students. The same percentage, (32%) of Lebanese university students were skipping fast food consumption. Previous studies have indicated that consumption of fast food was associated with weight gain and obesity (Malik et al., 2006; Bachman et al., 2006). Only (7.5% n= 15) of Lebanese students were consuming meat 1-2 times per week in comparison to Central Michigan University students (26%, n= 62). Moreover, (5.5%, n=11) of Lebanese students were consuming fish 1-2 times per week compared to (53%, n=126) of American students, and Canadian students (72%, n= 2262), (34%, n=69) of the Lebanese students were consuming eggs 1-2 times per week compared to (69%, n= 164) of American students. (45.5%, n=91) Lebanese students were consuming cheese more than 4 times per week in comparison to their American university peers (65%, n=154). Consumption of legumes more than 4 times per week which was considered the best eating habit among frequency of food consumption section included the only dietary habit that showed Lebanese students supremacy over their American peers since it was reported by (66%, n=133) of the Lebanese sample and (22%, n=52) of the American students of Michigan university. Prevention of weekly consumption of sweets, fried potato, pizzeria and ready-to-eat meat (Ham/salami/sausages), was reported by (16.5%, 1.5%, 4.5%, and 3% of the Lebanese students' samples respectively), and (11%, 50%, 0%, and 46% respectively) by the American students.

Our research few constraints. First, out of about 40 national private and public universities in Lebanon, the study sample only included one faculty from one institution: "The Lebanese University, Faculty of Education." Furthermore, it is challenging to establish the causative nature of the observed associations due to the cross-sectional approach of the study. Additionally, because the students self-reported their eating habits, the respondent may have underestimated the results or been biased. Nonetheless, the measurements of body composition were gathered using a scientific approach that resulted in validated tests that assessed body composition.

Conclusion

The study found that male students dominate body composition measurements, dietary habits, and nutrition knowledge, while female students show superior results in physical activity and lifestyle and dietary beliefs. Although females had a greater mean body fat percentage than males, both genders' values fell within the range of acceptable body fat percentages. In addition, although the Lebanese students showed satisfactory Nutrition habits having scored over average scores in the four nutrition sections, the healthiest Mediterranean Diet eating habits were reported by less than one-third of the Lebanese students' sample.

Lebanese students might benefit from college nutrition educational programs to convert theoretical nutritional knowledge into a practical daily-life eating pattern. Future research must study more lifestyle factors and health predictors such as physical activity and must approach diverse Lebanese population samples including different regions, socio-economic backgrounds, academic specialties, and ages. Also, future research in this field must utilize diverse objective measurement methods like personal interviews and high-technology methods. Researchers may be able to develop appropriate health promotion strategies that are tailored to the needs of students to encourage healthy eating habits, physical activity profiles, and positive lifestyle changes among students and create a healthy campus community. By implementing these recommendations and lifestyle guidelines, customized interventions and programs aimed at improving youth students' wellness and lifestyle behavior may be developed.

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Original article

Correlation of Morphological Characteristics with Police Specific Fitness Test in Police Students

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Abstract

This research delved into the potential correlation between morphological characteristics and the performance in a police specific physical ability test (PSPAT) among students at the University of Criminal Investigation and Police Studies. Of the 362 third-year students, 164 were female and 198 were male. The study assessed seven morphological traits: body height, body mass, body mass index, body fat, skeletal muscle mass, and their respective percentages. Body composition details were obtained using a multi-channel bioelectric impedance analyser. The Pearson correlation analysis was employed to understand the relationships between these features and the PSPAT outcomes. Results revealed that for female students, body fat, skeletal muscle mass, and their percentages significantly impacted their PSPAT performance. Male students, on the other hand, showed correlations with body fat and its percentage, but not with skeletal muscle mass. Interestingly, there were no significant associations between test results and body height, weight, or body mass index for all subjects. These insights emphasize the crucial role body composition plays in the physical capacities of police students, particularly focusing on the balance of muscle and fat content. This study's findings can inform future student selection, training methods, and the importance of comprehensive body composition assessments.

Keywords: Specialized Physical Education, Body Composition, Obstacle Course, Tactical Strength and Conditioning

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Introduction

Throughout their career, police officers (POs) may face critical incidents requiring high levels of strength, endurance, speed, and/or coordination. The level of basic physical abilities (BPA) and specific physical abilities (SPA) has the strongest impact on POs' work efficiency when the use of force is necessary, as well as when assisting endangered citizens during natural disasters (Strating et al., 2010; Lockie et al., 2020). For professional competencies to be developed, high-quality education of POs at specialized institutions is necessary, within which BPA and SPA can be improved (Dimitrijević et al., 2014; Janković & Dopsaj, 2022). This is significant since, after graduation, police students commence their careers as POs, hence potentially facing tasks the resolution of which is conditioned by their levels of physical ability (Koropanovski et al., 2020).

The selection of candidates at the University of Criminal Investigation and Police Studies (UCIPS) is multilayered. The first, eliminatory step, involved a health check, as well as a morphological and psychological characteristics check. Afterward, candidates are assessed by their high school success. Finally, their knowledge of the Serbian language and literature, general knowledge, as well as basic motor abilities are evaluated (Janković & Koropanovski, 2022). The entrance exam thus defined aims at singling out candidates presumed to possess adequate characteristics that would lead to them being efficient in the course of their studies, which, after education completion, enables them to attain appropriate professional competencies (Koropanovski et al., 2020). Considering the distinctiveness of UCIPS teaching curricula, it is essential that students be appropriately physically fit since it conditions the successful realization of certain specific aspe cts of the study program. Therefore, basic motor skills are also eliminatory in the UCIPS entrance exam, which is set at the 33rd percentile, in comparison with the average young and healthy population in the Republic of Serbia (Dopsaj, Vučković, & Blagojević, 2007; Janković. Kukuć, & Koropanovski, 2021).

Throughout their studies, students' physical abilities are assessed within the subject known as Specialized Physical Education (SPE). This assessment is conducted using a standardized battery of tests, which evaluates different types of strength, endurance, and speed. Furthermore, specific physical abilities relevant to their future roles as police officers are assessed through job-related fitness tests. One such test is the obstacle course for the assessment police specific physical ability (PSPAT) where students can demonstrate their specific agility (Janković & Dopsaj, 2022).The tasks conducted at PSPAT are equivalent to the realistic SPA that POs are required to possess during problem-solving incidents (chase, overcoming, removing). Likewise, the performance of all the tasks matches real professional conditions of problem-solving according to their structure (running with direction changes, overcoming obstacles, arrest simulation, etc.), as well as in terms of the time needed for their realization (the time necessary for test completion matches the average time of resolving a critical incident). All of the above is conducted in maximum and submaximum intensity, in the anaerobic-glycolytic regime of work, which is also in accordance with the intensity and physiological stress that occurs during the resolution of critical situations (Dopsaj & Janković, 2014, Janković et al., 2015).

As previously stated, during candidate selection for admission at UCIPS, basic morphological characteristics are observed. Those are body height (BH) and body mass (BM) (Janković & Koropanovski, 2022). The elimination standard is as follows. For women, minimum BH must be above 163 cm, whereas BM must be within the range of 3 kg extra, i.e., up to 12 kg less in accordance with BH subtracted by 100 cm. For men, minimum BH must be above 170 cm, while BM must be within the range of 10 kg more or less in accordance with BH subtracted by 100 cm. Research has shown that morphological characteristics could be linked with the ability of POs to perform their duty, especially if they are required to showcase their physical abilities such as combat, running, lifting heavy objects, etc. (Dawes et al., 2016; Kukić et al., 2018; Kukić et al., 2020). In other words, BH and BM may impact certain physical performances. Observing basic morphological characteristics (BH, BM, and by association, BMI) is the simplest and most commonly used procedure for body condition assessment. However, these measurements do not entail a more precise insight into body composition from the aspect of muscle and fat tissue. Furthermore, they do not reveal mutual relations of total fat, or fat distribution in certain body segments, which could vary significantly within normal body mass index (Akpinar et al., 2007). Besides, different body composition components may provide a better insight into a potential connection to BPA and SPA. Therefore, this paper aims at investigating the interconnectedness between morphological characteristics on the one hand, and the efficacy of POs at the specific agility test on the other. This work strives to offer a deeper insight into how body composition could influence professional physical performances within police work. The significance of this research might pertain to the enhancement of the selection system and training programs, from the aspect of tracking the changes in morphological characteristics.

Methods

Participants

This study includedd 362 undergraduate third-year students from the University of Criminal Investigation and Police Studies. The total sample was split into two groups, 164 female police students (FPS), with an average age of 21.6 ± 0.8 years; and 198 male police students (MPS), with an average age of 21.9 ± 1.1 years. All of the respondents partook in the research willingly, having been completely familiarized with the study's objectives and the manner of testing.

Measurements and Procedures

Morphological characteristics

Morphological characteristics were measured by means of a standardized method, using a bioelectrical impedance analysis – BIA, on InBody 720 Tetrapolar 8-Point Tactile Electrode System (Biospace, Co., Ltd), which utilizes the method of Direct Segmental Multi-frequency Bioelectrical Impedance Analysis.

The measurement procedure requires a specific preparation, i.e., that a respondent should not be physically active for at least several hours prior to the testing, as well as not to take huge amounts of food. Therefore, the testing took place in the morning hours. The measurement procedure is such that the respondents are in their underwear, with no jewelry, watches, or any other metal objects. Feet are placed on designated spots on the platform, whereas hands hold movable handles with electrodes. The respondents stand still until hearing the sound signal that marks the end of the measurement, after which their body composition is assessed (Völgyi et al., 2008). For the purpose of this work, the following variables were used: body height (BH), body mass (BM), body mass index (BMI), total body fat mass (BFM), total skeletal muscle mass (SMM), percentage of body fat (PBF) and percentage of skeletal muscle mass (PSMM).

Police Specific Fitness Test

The PSPAT was conducted at a designated place of 25x15 meters. The testing procedure included the measurement of the time needed to complete the task as an indicator of efficiency, i.e. the level of specific motor abilities. The candidates performed the PSPAT test presented in Figure 1 in accordance with the standard procedures that entail familiarizing oneself with the tasks, mock performances, adequate recovery, and test realization. The respondents performed the test wearing sports equipment, a belt with a holster, and a CZ 99 gun, together with a spare magazine with no ammunition, carrying official batons and handcuffs (Janković et al., 2020). The efficiency indicator was defined as the time of the PSPAT realization displayed in seconds, which was measured using a computer system for physical ability testing PAT 02 (UNO-LEX, NS, Serbia).

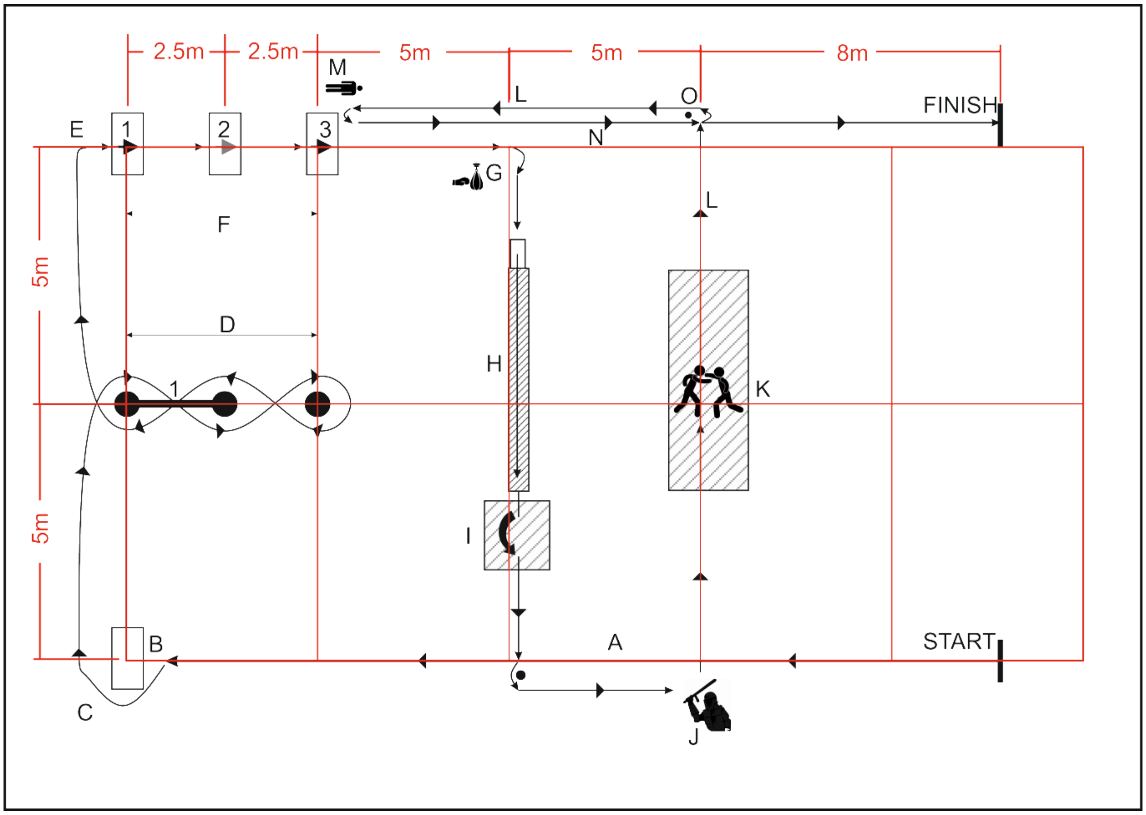

Figure 1. Obstacle course for the assessment of specific abilities of POs: A. Start at the sound signal and sprint 20 m in a straight line; B. Stop, take cover, and reach for a firearm; C. While holding the gun in the firing position, leave the cover from the left; D. Pass the cones from the outer side and crawl underneath the rope set at a height of 55 cm in marked spots. Distance between the cones is 250 cm; E. Stop and take cover, change the magazine, and put the firearm back into the duty belt; F. Three-part task: 1) Cross over a 110 cm-high obstacle; 2) Crawl beneath a 55 cm-high obstacle (F'); 3) Cross over a 110 cm-high obstacle. Distance between the obstacles is 250 cm; G. Approach the focus pad (held by an assistant), throw 4 punches and 2 kicks with maximum speed and intensity; H. Climb a 70 cm-high platform and cross a 120 cm-high and 500 cm-long balance beam; I. Leap on a mat with a forward roll; J. Approach a punching bag, take a baton, hit the bag 4 times with maximum efficiency and put the baton back on the duty belt; K. Reach the mats and defend against a predetermined attack, overcome the attacker using defence tactics, control and handcuff the suspect; L. Sprint 15 m at maximum speed, with a change of direction, towards the dummy (weighing 60 kilos); M. Reach the dummy; N. Carry the dummy (or drag it – optional for women) to a marked point (10 m); O. Safely place the dummy on the ground and run through the finish line.

Statistical analyses

The first step of data processing utilized a descriptive statistical analysis to calculate the parameters of measures of central tendency, measures of dispersion, and measures of distribution shape: arithmetic mean (Mean), standard deviation (SD), minimum and maximum values (Min, Max), the measure of results' skewness – asymmetry coefficient (Skew) and measure of the tailedness of results' – kurtosis coefficient (Kurt). The relation between the variables of morphological characteristics and the results of the PSPAT was ascertained utilizing the correlation analysis method *(Pearson correlation*) at the statistical significance level of $p < 0.05$. All statistical analyses were conducted using Statistical Package SPSS Statistics for Windows, Version 20.0.

Results

The descriptive statistics for PSPAT and morphological characteristics are shown in Table 1 for FPS, and in Table 2 for MPS. The results of the Pearson correlation between PSPAT and the morphological characteristics of the respondents of both sexes are shown in Table 3.

Table 1. Descriptive statistics for PSPAT and morphological characteristics for female students.

Variables	Mean	SD	Min	Max	Skew	Kurt
PSPAT (s)	94.5	8.5	71.3	118.4	-0.019	0.086
BH (cm)	169.6	5.1	162.2	183.2	0.219	-0.593
BM (kg)	63.1	6.8	48.2	87.6	0.538	0.584
BMI (kg/m^2)	21.9	2.1	17.7	28.3	0.843	0.798
BFM (kg)	15.5	4.1	6.2	29.1	0.687	0.761
SMM (kg)	26.2	2.6	20.3	33.6	0.215	-0.077
PBF (%)	24.3	4.6	12.6	36.2	0.169	-0.149
PSMM (%)	41.6	2.7	34.9	48.2	-0.162	-0.229

PSPAT – Specific physical abilities test; BH – Body high; BM – Body mass; BMI – Body mass index; BFM – Body fat mass; SMM – Skeletal muscle mass; PBF – Percent of body fat; PSMM – Percent of skeletal muscle mass.

Table 2. Descriptive statistics for PSPAT and morphological characteristics for male students.

Variables	Mean	SD	Min	Max	Skew	Kurt
PSPAT (s)	87.1	7.7	64.7	109.4	0.063	0.034
BH (cm)	182.3	6.6	172.9	197.3	0.147	-0.598
BM (kg)	82.4	9.3	62.7	112.7	0.735	0.699
BMI (kg/m^2)	24.7	2.3	19.4	32.1	0.537	0.140
BFM (kg)	12.4	4.4	4.5	26.7	0.792	0.464
SMM (kg)	39.9	4.3	30.4	56.7	0.785	1.097
PBF (%)	14.8	4.4	6.1	30.4	0.512	0.170
PSMM (%)	48.5	2.6	39.2	53.9	-0.457	0.173

PSPAT – Specific physical abilities test; BH – Body high; BM – Body mass; BMI – Body mass index; BFM – Body fat mass; SMM – Skeletal muscle mass; PBF – Percent of body fat; PSMM – Percent of skeletal muscle mass.

Table 3. Pearson correlation results between OC_{SAPO1} and morphological characteristics for FPS and MPS.

	FPS	BH	BM	BMI	BFM	SMM	PBF	PSMM
PSPAT	PCC	-0.007	0.006	0.002	0.212**	-0.194*	0.283**	-0.302**
	Sig.	0.931	0.944	0.982	0.007	0.013	0.000	0.000
	MPS	BH	BM	BMI	BFM	SMM	PBF	PSMM
PSPAT	PCC	0.091	0.073	0.017	0.165*	-0.017	0.170*	-0.189**
	Sig.	0.204	0.304	0.807	0.020	0.812	0.016	0.008

PSPAT – Specific physical abilities test; BH – Body high; BM – Body mass; BMI – Body mass index; BFM – Body fat mass; SMM – Skeletal muscle mass; PBF – Percent of body fat; PSMM – Percent of skeletal muscle mass.

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed)

Discussion

The primary findings of this study, in both FPS and MPS, show that BH, BM, and BMI do not significantly correlate to PSPAT ($p > 0.05$), i.e., that the mentioned morphological characteristics are not related to the specific agility test performance. On the other hand, the study reveals a link between PSPAT and BFM, PBF, and PSMM. The ascertained correlations point to the fact that a higher percentage of body mass leads to weaker results in the PSPAT, whereas a higher percentage of muscle mass causes the opposite effect. Finally, the study found a different correlation between PSPAT and SMM in FPS and MPS. Namely, as far as this variable in MPS is concerned, no statistically significant correlation was found, whereas there was a correlation in FPS (Table 3).

The results show that the impact of morphological characteristics on PSPAT varies between men and women, i.e., there is less correlation in MPS than in FPS. Previous research maintained that body composition differences between the sexes may influence professional task performance when running with direction changes is required. Besides, an additional professional load has a higher impact on women, which could be caused by the relatively heavier load they carry, when accompanied by their lower muscle mass (Kukić et al., 2020). Likewise, minimum professional load (a belt with equipment) has been proven to influence acceleration, running speed, and direction changes. As expected, the heavier the load, the more negative impact on physical performances, even more so in women than men (Kukić et al., 2023). A possible explanation for the higher correlation between morphological characteristics and PSPAT in FPS could lie in the manner of test realization, i.e., in the equipment the test is performed with. In the standard test procedure (Janković et al., 2015), respondents solve tasks with an additional load of a belt with equipment. This leads to FPS carrying a relatively heavier load in comparison with their body composition components, thus explaining their OC_{SAPO1} results' higher positive correlation to SMM and PSMM, as well as the negative correlation to BFM and PBF.

According to Strating et al. research (2010), in which 1432 female and 5567 male police officers participated, BMI is related to Physical Competency Test results (PCT). The findings of this study show that differences in time taken to complete PCT between men and women could indicate differences in physical readiness. What is more, higher BMI is linked to slower PCT performances for both women and men. Taking into account that body composition was not considered in this study (only BH, BM, and BMI), the supposition is that slower test completion may indicate a higher amount of fat mass, consequentially influencing their physical performances. The interconnectedness of body composition and BPA was established by Dawes et al. (2016). It was found that higher BFM diminishes performances in certain physical abilities (sit-up, vertical jump, 1.5-mile run, and estimated maximal voluntary oxygen uptake), indicating that increased BFM may have a negative impact on physical performances, probably due to the additional load that a body needs to carry. In combat sports, there are different categories, since higher BH and BM may be advantageous in contact (Dubnov-Raz et al., 2015), hence it is expected that more corpulent POs show greater efficiency in applied combat. However, Dillern et al. (2014) did not establish correlations between BH, BM, and BMI on the one hand, and SPA on the other (combat techniques application and arresting efficiency). Although it had been expected that POs with higher BMI would be more efficient in incidents where an opponent needs to be overpowered, the reason behind not establishing the mentioned correlation lies in the choice of partners during the overpowering and arresting test. The opponents were persons of a height and weight similar to the one of tested POs, in all likelihood resulting in more corpulent POs not having an advantage from a higher BM.

Problem-solving incidents most often consist of three relatively separate segments: 1. chase – running with direction changes and obstacle avoidance; 2. gaining control over a suspect – martial arts techniques application; 3. removal – taking the suspect away (Anderson, Plecas, & Segger, 2001), which are precisely the segments of the job-related fitness test OC_{SAPO1} (Figure 1). Not only has it been determined that higher height and mass could be useful in situations where the police must use physical force, but also that shorter POs with lower BM frequently obtain better results in tests for assessment of other physical abilities (Lagestad, 2012). We could presume that the advantage of BM and BH in overpowering and removing segments within PSPAT may also be a disadvantage in segments requiring faster direction changes, jumping over obstacles, etc. Therefore, one may conclude that no statistically significant correlations have been found between PSPAT and BH, BM, and BMI. However, there are correlations with body composition, especially with the relativized measures of PSMM and PBF. What is more, the lack of correlations may additionally be explained away by the fact that the testing was conducted with an extremely homogenous group in terms of age and selection process, which includes BH and BM, together with BPA assessment on an eliminatory level. The predefined standards excluded the option of entrance to obese candidates whose physical abilities could be assumed to have been at an insufficient level.

Conclusion

The core findings of this study indicate that morphological characteristics such as BH, BM, and BMI are not significantly linked to PSPAT in both sexes ($p > 0.05$). On the other hand, a statistically significant correlation has been found between PSPAT on the one hand, and BFM, PBF, and PSMM on the other. These correlations suggest that a higher amount and percentage of fat mass could negatively impact the performance of PSPAT, whereas a higher percentage of muscle mass has the opposite effect. Likewise, a greater correlation has been found in women than in men. Solely BMI (without body composition analysis) does not allow for a precise insight into the condition and mutual interconnectedness of structural components, such as total fat mass or fat distribution in particular body segments, and which can significantly affect certain physical abilities. It could be recommended to include the analysis of body composition in the process of selection and testing throughout the work career, from the aspect of establishing the amount and percentage of fat and muscle mass. This could further lead to more efficient identification of candidates best suited for specific physical requirements of police work, as well as those who might need special nutrition and training programs for the purpose of morphological characteristics regulation.

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