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The Importance of Physical Performance: Case study of University of Defence Cadets

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Abstract
The aim of the research was to analyze the physical performance of University of Defence (UD) students, explain the correlation structure of observed variables using exploratory factor analysis, and identify and name individual latent factors. A total of 89 male students from UD (age: 21.1 ± 1.26 years; body height: 180.3 ± 6.69 cm; body weight: 80.6 ± 9.32 kg) were tested as part of mandatory physical tests. For the examined group of UD students, basic statistical characteristics were calculated for individual variables (n = 18), and a seven-factor correlation structure of observed variables was identified through exploratory factor analysis (EFA).

KEY WORDS: *body composition, body size, exploratory factor analysis, military students, motor test battery, physical performance factors*

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1. Introduction

Physical fitness represents the cornerstone of military readiness. Armies worldwide are interested in ensuring that their soldiers are in the best possible physical condition. Physical fitness tests play a crucial role in evaluating and ensuring soldiers' readiness for demanding tasks. Military service performance is generally both mentally and physically demanding. Currently, various studies analyze the trend of declining physical fitness in the general population and specific groups, including soldiers. In some countries, there is a noticeable decline in endurance capabilities among military recruits at the beginning of their service, accompanied by an increase in body weight. Research by [2] (2007–2017) revealed some mild deterioration in certain physical fitness parameters among Czech Republic army recruits, although the findings cannot be generalized as some components showed slight improvement. Lower physical fitness levels in soldiers decrease the likelihood of successfully completing basic training and increase the risk of musculoskeletal injuries related to training. This also correlates with a higher probability of premature discharge from military service. Conversely, a high level of endurance, primarily general endurance, can positively impact the handling of physical demands during basic training and may be associated with successful completion thereof. When assessing military readiness, the main factors of performance are considered to be the level of strength and endurance capabilities. Long-term research has confirmed a positive trend in increasing performance among Czech soldiers in endurance and strength disciplines. Conversely, a study [9] examining the level of physical fitness among Czech army soldiers in 2015–2018 using standardized physical tests showed no significant changes in performance during those years. However, it is assumed that the general trend of deteriorating health and declining physical fitness due to lack of physical activity and poor dietary habits leads to an increase in body weight, percentage of body fat, and body mass index (BMI). A study [10] using the SFAS (Special Forces Assessment and Selection) test battery found that anthropometric data and body composition are predictors of soldiers' physical performance in the US Army. A narrow correlation between body composition and physical fitness in the US Army was also found in research [11]. Recent studies suggest that combined strength and endurance training is the most optimal training method for improving overall physical performance of soldiers. Soldiers involved in combat situations also require an appropriate level of anaerobic capacity to perform high-intensity tasks in rapidly changing life-threatening situations.

Significant differences in the initial physical performance of recruits have led military units to develop safer and more efficient training programs. Physical fitness of soldiers is often tested using tests designed for testing the general population, such as the 12-minute run and push-ups. Basic physical fitness tests for the majority of the population are conducted in light sports clothing, although most operational military tasks are performed in combat gear and body armor, increasing the weight carried and negatively affecting soldiers' overall performance. Lower body fat percentage (BF) and more fat-free mass (FFM) positively influence a soldier's performance in these tasks. In addition to general physical tests, specific military fitness tests assessing soldiers' performance in specific tasks and combat readiness have been developed. Soldiers perform tasks with combat loads including personal weapons, combat gear, etc. These high-intensity tasks typically include sprinting, lunges, climbing, rapid changes in movement direction, jumps, crawling, lifting and carrying loads, or casualty evacuation. Armies of various countries assess the physical readiness of military applicants and monitor the current level of physical fitness of all soldiers throughout the year using physical tests (test batteries) based on each army's internal regulations. Physical fitness training should focus primarily on developing endurance, strength, mobility, and flexibility considering the tasks soldiers must perform during service. There is no unified approach worldwide to the content of physical tests. NATO countries have their own test batteries, usually verifying strength (push-ups, sit-ups, pull-ups, and plank) and endurance (running various distances, especially 2–3 km) capabilities. Conversely, speed and coordination abilities are not typically tested. This also applies to swimming (except for the US Coast Guard). Some countries use specific tests such as load lifting and carrying (UK) or obstacle courses (Romania). Regular physical fitness assessments are conducted 1–2 times a year, often using similar test batteries as those used for army entry. The history of test battery development for the US Army was examined in their article [22]. They concluded that the relationship between the content of the APFT (Army Physical Fitness Test) and the requirements of current shared soldier tasks needs to be verified. [23] suggested that body fat percentage may be an important variable in determining or improving cardiovascular and muscular endurance, but not performance in the APFT. The APFT primarily focused on strength and endurance while neglecting key soldier activities such as dragging, lifting and carrying loads, or speed abilities. Therefore, the APFT was replaced by the ACFT (Army Combat Fitness Test), which focuses on combat readiness and better prepares soldiers for combat situations. [24] investigated the correlation of ACFT with body composition and body composition of army personnel. According to [26], another type of US Army test battery is the OPAT (Occupational Physical Assessment Test), which assesses recruits' physical abilities by measuring muscle strength, muscular endurance, cardiorespiratory endurance, explosive strength, and speed (standing long jump, seated medicine ball throw, deadlift, and interval aerobic run). Different variants of OPAT were also examined by [27]. The validity and reliability of other test batteries consisting of strength and endurance tests were examined by [28]–[29]. The combination of strength and endurance training is often used in athletics, the military, and for improving performance in the civilian population. As mentioned, physical training of soldiers in the Czech Republic and elsewhere focuses mainly on developing strength and endurance capabilities. In the Czech Republic, after successfully joining the army, military students can enroll in the University of Defense. As part of their studies, all soldiers must pass mandatory physical tests every semester, failure of which may lead to termination of their studies. Training and testing of military students at the University of Defense primarily focus on developing strength, speed, speed-coordination, and endurance capabilities. The aim of the research was to analyze the results of physical tests of UD students and to explain the correlation structure of the observed variables through exploratory factor analysis, identify, and name individual latent factors.

2. Methods

Participants

A total of 89 male students from UD (age: 21.1 ± 1.26 years; body height: 180.3 ± 6.69 cm; body weight: 80.6 ± 9.32 kg) were tested as part of mandatory physical tests. Ethical approval was obtained from the Human Subjects Ethics Committee of the University of Defence.

Procedures

The measurements and tests were focused on two areas (Table 1): body size and composition (6 tests), motor performance (12 tests). All tests were conducted by physical education professionals at the University of Defence, each possessing a minimum of five years of teaching experience. Participants were explicitly instructed to exert their best effort during each testing session. Testing of students took place at UD sports facilities and occurred over the course of one week.

Table 1.
Overview of anthropometric measurements and motor tests (n = 18)

Variables		**Jednotka**
Body size and composition		
1.	Body height (BH)	m
2.	Body mass (BM)	kg
3.	Waist hip ratio (WHR)	index
4.	Body fat (BF)	%
5.	Muscle mass (MM)	%
6.	Fat free mass (FFM)	kg
Motor performance		

7.	Handgrip strength right hand (SR)	kg
8.	Handgrip strength left hand (SL)	kg
9.	Forced expiratory volume in 1 second (FEV1)	litres
10.	Forced vital capacity (FVC)	litres
11.	Physical Working Capacity 170/kg (PWC170)	watts
12.	Sit-ups test 2 minutes (SU)	number
13.	Push-ups (PU)	number
14.	Triple jump (TJ)	meters
15.	Throwing a hand grenade (THG)	meters
16.	Running 5 km (Run5)	minutes
17.	Swimming 100 m (S100)	minutes
18.	Swimming 300 m (S300)	minutes

Body size and composition

Body size and composition measurements were conducted in the morning at the beginning of the first day of testing and included measurements of body height, body mass, and body mass index (BMI). Body mass index was calculated as body mass (kg) divided by body height squared (m^2). The measurements were conducted by trained personnel from Physical Training and Sports Centre in Brno. Test subjects arrived fasting and wearing light clothing after waking up. Body weight was measured without shoes using a calibrated electronic scale (InBody270, Soul, South Korea). To measure the amount of body fat and muscle (in %) relative to total body weight, the waist-to-hip ratio (WHR - an obesity indicator), and fat-free mass (FFM in kg = total body weight in kg - fat in kg), we used the InBody270 body composition analyzer.

Dynamometry

Maximal hand grip strength was measured with a hydraulic hand dynamometer Saehan DHD-1 (Saehan, South Korea). Dominant and non-dominant hand grip strength was assessed in a standing position, elbow extended, and the arm positioned with the dynamometer parallel to the subject's side. Participants were asked to perform a maximal voluntary contraction, squeezing the dynamometer as hard as possible for three seconds. The maximum force (in kilograms) achieved among two trials for each side was recorded.

Spirometry and cardiovascular endurance

We used a handheld spirometer to assess the most commonly measured parameters of lung function. These included the Forced Expiratory Volume (FEV, in liters), which is the total volume of air exhaled forcefully from the lungs after a deep inhalation. Additionally, the Forced Expiratory Volume in one second (FEV1, in liters) was measured, which is the volume of air exhaled forcefully within 1 second.

To determine and evaluate the adaptation of the cardiovascular system to endurance stress, the PWC170 test (Physical Working Capacity) was employed. A stationary bicycle ergometer of Cateye EC 1600 type controlled by computer software was used. This test, performed on a bicycle ergometer, does not require maximal effort, making it a submaximal intensity test. The result of the test is the power output (W) that the tested individual can achieve at a heart rate of 170 beats/min. Performance data were converted to kilograms of body weight (W/kg) for interpersonal comparison. The individual's heart rate determines the load size corresponding to their current physical fitness level. Upon mounting the ergometer, the tested individual familiarized themselves with the displayed data on the screen, adjusted the seat and handlebar height, and attempted pedalling at the prescribed pace (65 revolutions/min). After starting the test, the load on the ergometer is automatically adjusted by computer software to achieve the target heart rate of 170 beats/min. The basis is a 3-stage load, which is modelled by the computer based on the tested individual's heart rate values.

Sit-ups

Muscular endurance of the abdominal muscles was assessed via the sit-up test, where the recruits completed as many repetitions as possible in 120 s. The participants laid on their backs with their knees flexed to 90°, heels flat on the ground, and hands cupped behind their ears. The feet were held to the ground by a partner during the test. On the start command, recruits raised their shoulders from the ground while keeping their fingers were interlocked behind the head and touched their elbows to their knees. The recruit then descended back down until their joined hands touching the ground and completed as many repetitions as possible.

Push-ups

Upper body strength endurance was assessed using the maximal push-up test, where participants performed as many repetitions as possible. Participants started in the standard "up" position, with the body stretched and straight, with the arms positioned shoulder width apart with the fingers pointing forward. They lowered themselves until their chest touched the ground, and then stretched into elbows and returned to the starting position. The recruits performed as many push-ups as possible using this technique.

Triple jump

Explosive strength of the lower limbs was measured using a standing triple jump. The participant performed three consecutive jumps from a standing position with feet hip-width apart, utilizing a simultaneous swinging motion of the upper limbs. The total length of the jump (in meters) from the takeoff line to the nearest heel touch point was evaluated.

Throwing a hand grenade

The explosive strength of the upper limbs was tested by throwing a 350g dummy grenade. Participants threw it in any manner (three attempts, measured in meters) into a designated sector.

Swimming 100, 300m

Participants swam using any stroke, and they could switch strokes during the test. The achieved time was evaluated (with accuracy to one second).

3. Statistical analyses

Descriptive statistical methods (mean, standard deviation; minimum value, maximum value; coefficient of variation; Pearson correlation coefficient) were used for statistical data analysis. The correlation structure of observed variables and identification of individual factors were examined using exploratory factor analysis (maximum likelihood method, varimax rotation). The effect size of the correlation coefficient r was evaluated as follows (Cohen, 1988): $r = 0.1$ (small); $r = 0.3$ (medium); $r = 0.5$ (large). The level of significance was chosen to be $p = 0.05$.

4. Results

An overview of basic statistical characteristics (somatic and motor) of all participants is provided below (see Table 2). Participants ($n = 89$) were aged 20.0–26.0 years (age: 21.1 ± 1.26; body height: 180.3 ± 6.66; body weight: 80.6 ± 9.26). The coefficient of variation (CV) values for somatic indicators ranged between 3.7–18.2 %, with the least variability observed in body height and the greatest in body fat percentage.

Table 2.
Basic statistical characteristics – body size and composition ($n = 89$)

Variables	Age	BH	BM	WHR	BF	MM	FFM
M	21.1	180.3	80.6	0.8	20.9	73.3	63.6
SD	1.26	6.66	9.26	0.03	3.80	3.79	6.40
Min	20.0	164.6	61.1	0.70	11.4	64.1	50.8
Max	26.0	196.0	102.4	0.90	30.2	82.6	82.7
CV	6.0	3.7	11.5	3.8	18.2	5.2	10.1

Notes. BH = body height (cm); BM = body mass (kg); WHR = waist hip ratio (index); BF = body fat (%); MM = muscle mass (%); FFM = fat free mass (kg); M = mean; SD = standard deviation; Min = minimum value; Max = maximum value; CV = coefficient of variation (%)

In Table 3, basic statistical parameters of the results of motor tests for the entire sample are provided. The coefficient of variation (CV) values for motor indicators ranged between 6.1–22.0 %, with the least variability observed in the triple jump and the greatest in push-ups.

Table 3.
Basic statistical parameters – motor performance ($n = 89$)

Variables	HSR	HSL	FEV1	FVC	PWC	SU	PU	TJ	THG	RUN5	S100	S300
M	51.2	48.5	4.3	5.2	3.1	79.0	41.0	7.67	44.0	22:35	1:50	6:42
SD	7.62	7.53	0.65	0.71	0.43	9.20	9.04	0.47	6.49	1.61	0.24	0.65
Min	31.1	29.0	2.2	3.3	2.2	65	26	6.3	27	18:24	1:09	4:47
Max	68.4	65.1	6.2	7.0	4.3	105	70	8.6	70	26:23	2:15	8:30
CV	14.9	15.5	15.1	13.7	13.9	11.6	22.0	6.1	14.8	7.2	16.0	10.1

Notes: HSR = hand grip strength right hand (kg); HSL = hand grip strength left hand (kg); FEV1 = forced expiratory volume in 1 second (litres); FVC = forced vital capacity (litres); PWC = physical working capacity (170/kg; watts); SU = sit-ups test 2 minutes (number); PU = push-ups (number); TJ = triple jump (meters); THG = throwing a hand grenade (meters); Run5 = running 5 km (minutes); S100 = swimming 100 m (minutes); S300 = swimming 300 m (minutes)

For the examined group of UD students (n = 89), basic statistical characteristics were calculated for individual variables (n = 18), and a seven-factor correlation structure of observed variables was identified through exploratory factor analysis (EFA). The values of the correlation coefficient *r* between individual variables and factors F1–F7 are provided below (see Table 4).

Table 4.
Structure matrix coefficienfts for observed variables (n = 18)

Variables	F1	F2	F3	F4	F5	F6	F7
BH	*(-0.195)*		0.591		0.479		
BM	0.423		0.806	0.329			
WHR	0.933						
BF	**0.973**						
MM	-0.971						
FFM			**0.898**	0.363			
HSR				0.818			
HSL				**0.903**			
FEV1					**0.837**		
FVC					0.772		
PWC		0.480					
SU		0.430					
PU		**0.782**					
TJ							0.433
THG							**0.630**
RUN5		-0.437					-0.356
S100						**0.975**	
S300						0.756	

Notes: For α = 0,05 is r_{krit} = 0,206. Factor loadings <0.3 (ES small) are suppressed. Variables with the highest loadings for each factor are in bold.

The individual latent factors can be designated as follows: F1 = "body size and composition" (highest loadings found in body fat, .973), F2 = "strength endurance" (highest loadings found in push-ups, .782), F3 = "body size" (highest loadings found in fat-free mass, .898), F4 = "*muscle strength*" (highest loadings found in HGS left, .903), F5 = "*vital lung capacity*" (highest loadings found in forced expiratory volume, .837), F6 = "*swimming skill*" (highest loadings found in swimming 100 m, .975), F7 = "explosive strength" (highest loadings found in throw a hand grenade, .630). Based on the results of EFA, the reduction of the number of measurements and tests to a total of seven can be considered, using variables with the highest loadings.

5. Discussion

The results of the analysis of physical performance among Defence University students based on anthropometric and motor characteristics can be compared with several other studies [1], [2], [6], [8], [10], [17], [23], [28] allow for partial comparisons with our results in the area of anthropometric and motor characteristics. The results from a study examining the developmental trends of American recruits (soldiers) between 1975 and 2013 indicated that in the last year tested (2013), the value of BM (mean = 80.0 kg) was the same as in our study. The values of FFM (mean = 69.4 kg) were slightly higher (+5.8 kg), while BF (mean = 17.5 %) was lower (-3.4 %). The study showed minimal temporal changes over the years in terms of body height, while body weight, body fat, and lean body mass increased over the years. Test results for muscle endurance (push-ups, sit-ups) demonstrated negligible changes over time [1]. Another study of American soldiers (n = 795) examined anthropometric data, body composition, and their impact on physical performance (selection for SFAS = Special Forces Assessment and Selection). Selected soldiers had higher BH (179.0 ± 6.60 cm), BM (85.8 ± 8.80 kg), LBM (lean body mass), values of which did not differ much from FFM (67.2 ± 7.30 kg) and BF (17.3 ± 3.4%) compared to unsuccessful candidates. Similar average values compared to ours were achieved for BH, LBM, with higher values for BM (+5.2 kg) and LBM (FFM, +3.6 kg), and lower for BF (-3.6 %). It was found that lower height predicted better performance in push-ups and pull-ups, while taller stature predicted better performance in running and marching with a load [10]. According to another study, soldiers with BF ≤ 18 % achieved significantly better results in seven out of ten physical fitness tests (Group 1; n = 44; age: 26.6 ± 6.10 years; BH: 176.8 ± 8.64 cm; BM: 76.4 ± 9.54 kg; BF: 13.3 ± 3.70 %; FFM: 66.8 ± 8.20 kg; SU: 73.6 ± 16.20). Lower values compared to ours were achieved for BH (-3.5 cm), BM (-4.2 kg), SU/2 min. (-5.4). Soldiers with similar FFM but less body fat had better aerobic and anaerobic capacity and greater muscle strength [17]. Similar BH and BM values but significantly lower BF (-7.2 %) compared to ours were achieved in a study of American military cadets (n = 11; age: 21.8 ± 3.80 years; BH: 179.1 ± 8.13 cm; BM: 78.6 ± 10.31 kg; BF: 13.7 ± 2.8%). A significant negative correlation between SU and BF was also demonstrated [23]. Lower BH (-5.3 cm), SU/2 min. (10), and similar BM and BF values compared to ours were achieved in another study of American soldiers, where test battery results significantly correlated with LBM (n = 41; age: 22.0 ± 3.00 years; BH: 175.0 ± 8.00 cm; BM: 81.4 ± 12.90 kg; BF: 22.0 ± 5.70 %; SU = 69.0 ± 11.00) [28]. Similar values for push-ups (38.5 ± 12.70) compared to our study were recorded after the first week of training for recruits in the Australian army (n = 184) [6]. Long-term monitoring of the physical fitness of Czech army personnel (men; n = 268; age: 29.3 ± 4.70 years) showed average values for push-ups (32.1 ± 0.73), which is less than in our study (-8.9) and for swimming 300m (5:41 ± 0:05 min), which is less (1:01 min.), but in this case indicates better performance. According to the authors, there was an overall improvement in strength and endurance disciplines over the period studied (2012–2019) [8]. Comparison with the PWC170 test is possible only through a study examining Czech recruits between 2000 and 2017, where slightly lower values (mean = 2.83 W/kg) were recorded compared to ours [2].

6. Conclusions

The analysis of physical performance of University of Defence students using exploratory factor analysis demonstrated a seven-factor structure of observed variables. The individual latent factors can be identified as "body size and composition, strength endurance, body size, muscle strength, vital capacity, swimming skill, explosive strength." The reduction of the original eighteen measurements and tests to a total of seven can be considered.

Limitations

Although there are methods for determining the optimal number of factors when using EFA, the interpretation of factors may depend on the researcher's subjective assessment and knowledge. Selecting inappropriate methods for analysis (e.g., incorrect type of factor analysis) can lead to incorrect results. If too many factors are selected, it may lead to excessive model complexity and difficulties in interpretation.

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