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Factorial and Construct Validity of Sit-Up Test of Different Durations to Assess Muscular Endurance of Police Students

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Abstract: Background: The number of completed sit-ups in a given period of time is a commonly used assessment to measure trunk endurance in tactical populations. This study investigated factorial and construct validity of three different durations of a sit-up test—30 s, 60 s, and 120 s; Methods: Anthropometric characteristics and sit-ups performed for 30, 60, and 120 s by101 (♂: n = 62 and ♀: n = 39) police students were assessed. A factorial analysis was used to determine if three test durations group together in one factor, correlation analysis determined whether the sit-up tests were associated with anthropometric measures and whether the three variations in the test duration correlated between each other, and the Fisher's transformation determined whether these correlations differed significantly; Results: All three sit-up variations loaded together into one factor in both sexes, providing factorial validity for all three test durations. Anthropometrics were associated with sit-up tests lasting 30 s in males and 120 s in females. A sit-up test lasting 60 s correlated significantly stronger to 120 s than to the 30 s sit-up test; Conclusions: The 60 s sit-up test seems to have the highest construct validity, as it was not affected by anthropometrics, and it may be an optimal choice for its lower risk of lower back injuries. By applying the results of this study, agencies could reduce the bias that may occur during the sit-up test and reduce the risk of injury during physical fitness assessment.

Keywords: sit-up; assessment; tactical population

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1. Introduction

Police students are educated and trained to perform the job of a police officer, a job that requires a wide range of physically demanding occupational tasks [1,2]. As such, physical fitness assessments are typically part of the recruitment process for most police agencies [3,4]. Additionally, physical training is generally considered an integral part of a student's study process [5–7] with the expectation that a certain level of physical fitness will be maintained once police students become officers.

Several components of physical fitness have been identified as important to this population, including body composition, aerobic endurance, and muscular endurance [1,8,9]. Muscular endurance represents the ability of muscles to contract repeatedly or isometrically for an extended time, typically ≥30 s [10,11]. Trunk muscular endurance bears importance in these populations in regard to stabilizing body posture with and without occupational load [12,13], use of force scenarios, lifting/carrying, twisting, running, and stair descent [1,14,15].

Physical fitness assessments have been used by police agencies for recruiting, planning physical training programs, and screening for cadet and officer physical fitness. One of the most commonly used tests of muscular endurance by police and military agencies has been the number of sit-ups (SU) performed in a given time period [8,9,16]. The SU test is simple and can be easily administered in large groups within a reasonably short period of time. However, multiple variations of the test exist. For example, some agencies use a SU test with participants' hands crossed over the chest [17], whereas others have participants' cup their hands behind their ears [4,15,18]. One example of manipulation related to variations in time to complete the assessment is using the duration of 30 s [3,4], 60 s [5,18], or 120 s [15,17,19]. Duration is of importance as, for example, a SU test lasting for 30 s could result in largely using the anaerobic lactic system, whereas the SU lasting 60 or 120 s could rely more on the oxidative system compared to a shorter duration test.

However, whether 30, 60, or 120 s should be used for the assessment of muscular endurance may depend on a variety of factors. For instance, larger and smaller individuals of the same body composition (i.e., similar percent body fat and percent of skeletal muscle mass) and fitness level may perform. Therefore, the purpose of this study was to evaluate three commonly used sit-up tests against each other and against the human anthropometric characteristics, thus providing an evidence for the optimal choice of sit-up test. The first aim of this study was to investigate the factorial validity of SU test variations in duration. The second aim was to investigate whether body anthropometrics, such as body height, seated height, and body weight, were associated with SU test performance of different durations. The third aim was to determine whether the performances of SU tests of different durations were associated with each other. It was hypothesized, first, that test durations would provide factorial validity; second, that anthropometric measures would be associated with SU test performance; and third, that the association of different durations of the SU test would differ between the tests.

2. Materials and Methods

2.1. Participants

The sample consisted of 101 police students (♂: n = 62 and ♀: n = 39) from the University of Criminal Investigation and Police Studies (UCIPS), Belgrade, Serbia. All participants were from the second year of studies. Their average age was 21.2 ± 1.5 years. They were engaged in three physical education classes per week, with two focusing on self-defense, and one focusing on strength and conditioning. Given that to enroll in the studies they had to perform a sit-up test and that during the first year of studies they had physical education classes and the assessment at the end of the year, they were familiar with the testing procedures. They were assessed in the morning hours between 08:00–10:00. Participants were informed about the aim of the data collection and signed an informed consent allowing the data to be used for research. The research study was approved by the Ethics Committee of the UCIPS (IRB No. 440/2) and conducted in accordance with the conditions of the Declaration of Helsinki, considering the recommendations made by guiding physicians in biomedical research involving human subjects [20].

2.2. Anthropometrics

The anthropometric measurements, body height (BH) and body mass (BM), were measured with a Seca 769 weight scale and a height measuring rod (Seca, Hamburg, Germany). Anthropometric measurements were conducted between 8:00 a.m. and 10:00 a.m., whereby all participants fasted the night before the measurements were taken and were advised not to eat a large meal for dinner and not to exercise the day prior to the measurement. For the BH measurement, participants stood with their back straight and head in the Frankfurt plane position. One measurer sat appendicular to the participant, controlling the position of the participant and wiring down the result that the second measurer collected from the rod. Sitting height (SH) was measured while participants were in a sitting position, with their back and head holding next to the wall, looking straight (head in the Frankfurt plane position). BM was measured while participants were in underwear, barefoot, and had all accessories removed. Measurements were recorded to the nearest 0.5 cm and 0.5 kg, respectively. To analyze the association of torso length to SU variations, a ratio between the SH and BH was used (SHtoBHratio). Body mass index (BMI) was used as an indicator of integrated body volume and size (kg/m^2). These anthropometric measures were used because human bodies differ in longitudinal and transversal body size and these measures provided us with the ability to investigate to what degree SU tests are explained by natural body size differences in people.

2.3. Sit-Up Test Duration Variations

The same form of a sit-up test (SU) was conducted under three different conditions based on variations in duration: those being 30 s (SU30s), 60 s (SU60s), and 120 s (SU120s). Each test was conducted on a separate day, with a minimum of 48 h of rest in between two tests, while the testing order was randomized. Although the participants had been using the SU exercise and test extensively during their regular physical education classes, in a week before the testing, all participants were thoroughly briefed about the correct technique for the SU tests and the rules of the testing. During that week, they also had two physical education classes where they were familiarized with the techniques and rules. A 5 min general and 5 min specific warm-up preceded testing. The starting and finishing positions for the SUs were laying down with their back on a mat, knees bent at about 90 degrees, fingers intertwined on the occipital bone, and both elbows in an 'open' position to touch the floor. They were not allowed to disconnect their fingers and move their hands from the occipital bone. Slight movements of their elbows were allowed to obtain the natural flow of the whole sit-up movement. However, rapid forward movement (i.e., swing) was not allowed. Feet were placed flat and wholly on the ground and were tightly secured by a fellow participant. At the end of each repetition, both shoulder blades had to touch the ground before the start of the next repetition commenced. Hips had to maintain contact with the ground and fingers had to remain intertwined behind the neck during the full range of movement throughout the test. The only permissible resting position was when the participant was in an upper position (i.e., stomach and chest touching the thigh and knees). Repetitions not meeting these standards were not counted. The requirement in each variation of the test was as many SU as possible for given time, whereby in SU30s participants were additionally instructed to do the repetitions as fast as possible. Participants were strongly encouraged to give their maximum and were verbally supported throughout the test.

2.4. Statistics

The descriptive statistics for mean, standard deviation (SD), minimum (Min.), and maximum (Max.) were analyzed according to the sex of the participants. A principal component analysis (oblimin rotation) was used to investigate how many independent factors explain the variance between the subjects and if the measured SU test variations fell into the same factor. An eigenvalue over 1 was used to define significant components, correlation coefficient of over 0.6 was used to define the component loading, and the uniqueness was checked for variables within each extracted component. The Pearson's correlation coefficient was used to establish the relationship between the SU test and variables from different factors and between variations of the SU tests. A Fisher's r to Z transformation was used to analyze the between- and within-sex differences in correlation with the SU test. The significance level was set to $p < 0.05$. The effect size of correlation coefficients was defined as weak = 0.20—0.49, moderate = 0.50—0.80, or strong $\geq$ 0.80 [21]. All statistical procedures were conducted using the Statistical Package for Social Sciences (IBM, SPSS statistics, version 23, Chicago, IL, USA) and JASP (version 0.16.3).

3. Results

The descriptive statistics for Mean, SD, Min., and Max. for both sexes are shown in Table 1.

Table 1. Descriptive statistics for anthropometrics and sit-up tests.

Variables	Male (n = 62)				Female (n = 39)			
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
BH (cm)	182.00	5.19	173.00	195.00	169.92	3.15	165.00	176.00
BM (kg)	79.52	8.33	60.00	97.00	62.77	6.42	50.00	78.00
BMI (kg/m^2)	23.96	1.81	20.05	28.34	21.73	2.09	17.72	26.99
SH (cm)	91.60	2.51	86.00	97.00	87.67	3.05	77.00	92.00
SHtoBHratio	0.50	0.01	0.48	0.54	0.52	0.02	0.46	0.54
SU30s (No)	23.11	2.04	18.00	27.00	21.23	1.69	18.00	24.00
SU60s (No)	41.16	4.16	34.00	50.00	38.54	4.66	29.00	48.00
SU120s (No)	55.29	10.12	36.00	84.00	52.69	9.94	33.00	71.00

Note: BH: body height; BM: body mass; BMI: body mass index; SH: sitting height; SHtoBHratio: ratio between sitting height and body height; SU30s: number of sit-ups in 30 s; SU60s: number of sit-ups in 60 s; SU120s: number of sit-ups in 120 s.

The principal component analysis extracted three independent factors in males as well as females. The structure matrix revealed the variables that entered each of three factors in males (Table 2) and females (Table 3). BM, BMI, and SH entered the first factor in males, explaining the largest portion of variability between male participants. Considering the males, in total, 82.98% of the between-subject variance was explained, whereby the first factor explained 38.00%, the second explained 26.68%, and the third explained 18.22% of the variance. The SU60s, SU120s, and SU30s entered the second factor, whereas SHtoBHratio and BH from the third factor explained the smallest portion of variance. In females, 81.41% of the variance was explained by three factors, each of which explained 44.07%, 20.23%, and 17.11%, respectively. The SU30s, SU60s, and SU120s explained the largest portion of between-subject variance, followed by the BM and BMI from the second factor, and SHtoBHratio and SH from the third factor.

Table 2. Structure matrix for male police students.

Variable	Factors		
	1	2	3
BM (kg)	0.929	−0.214	−0.393
BMI (kg/m^2)	0.792	−0.270	−0.035
SH (cm)	0.787	0.182	0.283
SU60s (No)	0.067	−0.940	−0.156
SU120s (No)	0.012	−0.888	0.007
SU30s (No)	0.297	−0.733	−.0464
SHtoBHratio	0.108	0.206	0.967
BH (cm)	0.647	−0.026	−0.689

Table 3. Structure matrix for female police students.

Variable	Factors		
	1	2	3
SU60s (No)	−0.894	−0.192	−0.310
SU120s (No)	−0.878	−0.381	−0.164
SU30s (No)	−0.825	−0.264	−0.269
BH (cm)	0.526	0.227	−0.340
BM (kg)	0.382	0.991	0.019
BMI (kg/m^2)	0.209	0.972	0.148
SHtoBHratio	0.198	0.126	0.994
SH (cm)	0.472	0.247	0.798

Correlation analysis revealed significant interactions between the SU tests variables from different factors as well as between the SU tests of different durations (Figure 1). The correlation coefficient between the SU30s and SU60s was moderate in both sexes, whereas correlation between the SU30 and SU120s was small in males and moderate in females. Finally, the correlation between the SU60s and SU30s was large in males and moderate in females.

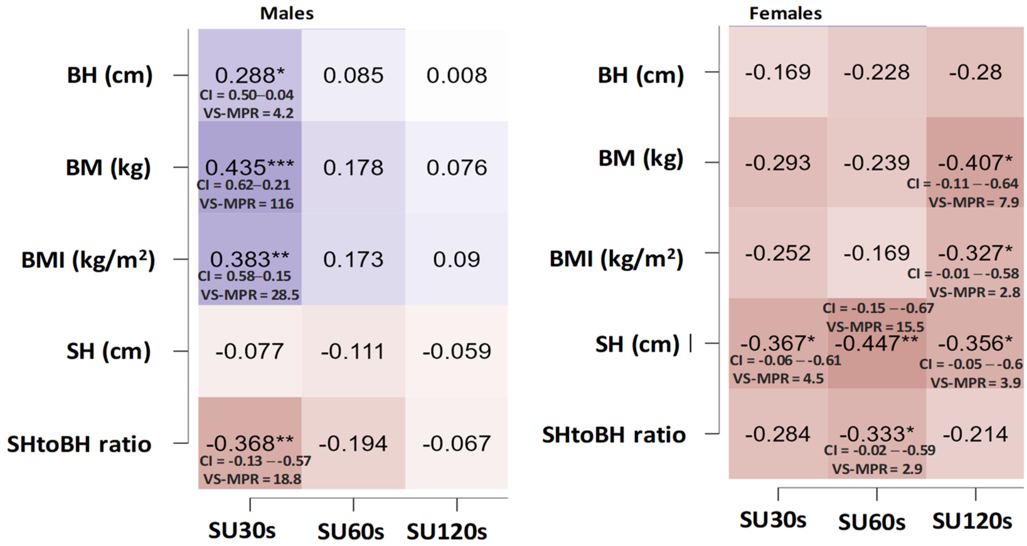

Figure 1. Correlation analysis between the SU tests and anthropometrics. Note: * Significant at $p < 0.05$, ** Significant at $p < 0.01$, *** significant at $p < 0.001$, VS-MPR–Vovk-Sellke Maximum p-Ratio, CI-95% confidence interval.

Fisher's transformation analysis showed that the correlations were not statistically significant between sexes for correlation between SU30s and SU60s (Z = −1.28, p = 0.201), SU30s and SU120s (−1.58, p = 0.114), and SU60s and SU120s (Z = 0.460, p = 0.646). However, considering the within-sex differences, the correlation between the SU30s and SU60s, SU30s and SU120s, and between SU60s and SU120s were significantly different in males, with correlation between the SU60s and SU120s being significantly higher (Figure 2).

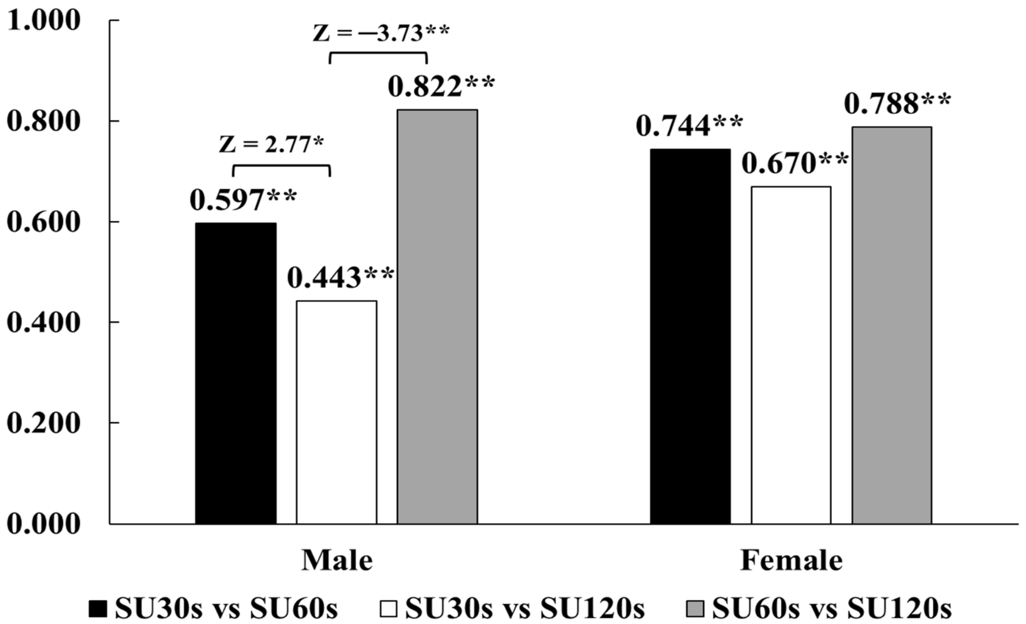

Figure 2. Differences between the correlations of different SU test variations. Note: * Significant at $p < 0.05$, ** Significant at $p < 0.01$. SU30s vs. SU60s—the correlation coefficient between the SU30s and SU60s, SU30s vs. SU120s—the correlation coefficient between the SU30s and SU120s, SU60s vs. SU120s—the correlation coefficient between the SU60s and SU120s.

4. Discussion

The purpose of this study was to investigate the factorial validity of different durations of SU test, the association of anthropometric measures to SU test performance, and whether SU tests of different durations were related to each other. The factor analysis revealed that the three SU variations loaded into one independent factor in both sexes, which agreed with the first hypothesis. Therefore, all three SU durations evaluate trunk muscular endurance. However, SU60s loaded the highest correlations in both sexes suggesting that this duration may be the optimal choice as it explains the highest percentage of between-participant variation.

Significant moderate correlations were discovered between anthropometrics and SU test performances. These correlations were different for males and females as BH, BM, and BMI correlated with SU30s in males in contrast to SU120s in females. In addition, SH was associated with each SU test in females. Therefore, the second hypothesis was partially accurate, which suggests that subjects of different body frames and BM may perform differently in certain SU tests. Finally, significantly different between-test correlations occurred in male but not in female police students, providing that the third hypothesis was true for males but not true for females.

Supporting the results of this study, the findings by Dawes et al. [18], in a sample of 76 law enforcement officers, suggested a non-significant correlation between a SU60s test and body composition characteristics such as percentage of body fat (%BF), lean mass, and body fat mass. In contrast, a study on a sample of part-time SWAT officers found significant associations between the SU60s assessment and BMI, chest skinfold, abdominal skinfold, thigh skinfold, and sum of skinfolds [22]. However, the authors did not find a significant relationship between the SU60s test and BM. It is of note that the sample that informed this study and the sample of Dawes et al. [18] were relatively homogenous by participants' body composition, with majority of participants not being obese, whereas participants in the study by Dawes et al. [22] were, on average, obese (mean BMI = 30.10 kg/m^2). In addition, the results of this study are similar to those reported by Peterson et al. [19] who found a non-significant correlation between torso length and a 120 s SU test among military personnel. Therefore, the evidence suggests that increased body fatness rather than body dimensions may have a greater influence on SU test performance.

Increased body fatness in police officers typically relates with poorer fitness [23] and lack of physical activity [24,25], which could, in turn, be the reason for lower SU performance in assessment that lasts 60 or 120 s. Given that in females BH did not, while BM and BMI did correlate to SU performance, it may be that those with increased body mass relative to their height had higher body fat mass. Similarly, Esco et al. [26] reported significant correlations between the SU60 test and BMI, waist circumference, abdominal skinfolds, and BM. However, almost one third of their sample had a waist circumference that indicated an increased health risk, followed by a BMI of about 36.34 kg/m^2. It may be that for officer's whose fitness is poorer and body fatness higher, the negative effect on SU performance will occur at SU60 durations rather than only at longer 120 s durations. Moreover, increased abdominal fatness may obstruct the movement mechanics of the sit-up, making the movement less efficient and more costly [27].

The analysis of the inter-test correlation revealed weak-to-strong associations between three test durations, corroborating the second hypothesis. However, these results indicate a gap between the test durations in males, even though all three durations could be considered sufficient for the evaluation of muscular endurance. The strongest associations occurred between SU60s and SU120s in both sexes, whereas the correlation in male subjects between SU30s and SU60s was significantly smaller compared to those that occurred between SU30s and SU120s or SU60s and SU120s. Therefore, it seems that the SU60s and SU120s could be considered to evaluate the same physical ability (i.e., oxidative muscular endurance). The SU30s moderately corresponded to the longer two tests, with decreasing trends of association, explaining 59.7% and 44.3% of the same variance in SU60s and SU120s, respectively. This could be due to the higher intensity (i.e., higher repetition rate per second) of the SU30s, which largely depends on the anaerobic lactic energetic system (i.e., anaerobic endurance). Given that the mean BMI of males was 23.96 kg/m^2, positive correlations with SU30s test may occur due to better muscular strength and power that are often followed by increased skeletal muscle mass [28]. Thus, those officers that possess greater upper-body power may be able to perform more repetitions when the duration is relatively short.

The functional anatomy of muscles involved in sit-ups assessments also play an important role when considering the results of this study. As the sit-up activity has an increased use of the hip flexor group once past approx. 30 to 45 degrees of trunk flexion [29], there is a greater potential for imparted muscle forces to pull the pelvis into anterior tilt increasing lumbar spine lordosis [30]. Increased lumbar spine lordosis associated with anterior pelvic tilt can also lead to lumbar vertebral joint compression and increased shear forces [30]. This in turn may exert large shear and compressive forces to the lumbar spine during sit-ups [30,31] and lead to a myriad of unwanted loading responses and pathologies [30]. Therefore, as situps can produce greater moments and forces through the lumbar spine, being able to assess trunk endurance using a shorter duration sit-up test (in light of other alternatives such as a curl up) may be beneficial for injury mitigation [30,32]. This consideration of sit-up duration and lumbar spine loading is of note given that the lower back is a leading site of injury in law enforcement personnel [33].

The sample sizes for males and females could be larger. The sample's characteristics such as age and anthropometrics were relatively narrow and widening them by including duty officers may be beneficial in the future. Body composition characteristics such as percent of body fat and skeletal muscle mass could also be included for more accurate comparisons with previous studies. In addition, the physical fitness level of the sample could be more disperse. However, the significance obtained on this relatively homogenous sample suggests that the effect sizes could be even higher with a larger sample of larger data dispersion. Moreover, the more disperse sample might mitigate the differences between the SU30s, SU60s, and SU120s, thus lowering the potential importance of the test duration for injury prevention.

5. Conclusions

This study showed that three common variations in the duration of the sit-up test analyze the same physical ability. However, significant association of anthropometrics with SU test performance suggest that SU60s may be an optimal choice as that was the only duration that was not associated with anthropometrics. Therefore, SU60s seem to provide indication of muscular endurance that is not biased by anthropometrics. This may be of high importance for agencies as they tend to set the unbiased policies of physical fitness assessment. Furthermore, the results of this study could be used by strength and conditioning personnel working with police officers in applying the training load for abdominal muscles more accurately. Moreover, noting that the sit-up is a commonly used assessment in law enforcement and that forces can be transferred to the lower back, a common injury site in police officers, a duration of 60 s may be the optimal for this assessment. However, the joint contact forces and musculoskeletal loading in these variations of the SU test could be investigated in the future. In addition, the activation of muscles involved in the SU test could be investigated.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data is available upon request from filip.kukic@gmail.com or nenad.koropanovski@kpu.edu.rs.

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