Analysis of total and segmental body composition relative to fitness performance measures in law enforcement recruits

Collins, Kyle; Christensen, Bryan; Orr, Rob Marc; Dulla, Joseph; Dawes, Jay; Lockie, Robert

Published in:
International Journal of Exercise Science

International Journal of EXERCISE SCIENCE

Original Research

Analysis of Total and Segmental Body Composition Relative to Fitness Performance Measures in Law Enforcement Recruits

KYLE S. COLLINS†1, BRYAN K. CHRISTENSEN‡1, ROBIN M. ORR‡2, JOSEPH M. DULLA‡2, J. JAY DAWES‡3, and ROBERT G. LOCKIE‡4

[1]Department of Health, Nutrition, and Exercise Sciences, North Dakota State University, Fargo, ND, USA; [2]Tactical Research Unit, Bond University, Robina, QLD, AUS; [3]School of Kinesiology, Applied Health and Recreation, Oklahoma State University, Stillwater, OK, USA; [4]Center for Sport Performance, Department of Kinesiology, California State University, Fullerton, Fullerton, CA, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 15(4): 245-260, 2022. Law enforcement agencies often test the fitness performance and body composition of incoming recruits. This study investigated the relationships between whole and segmental body composition, and fitness tests in law enforcement recruits. A retrospective analysis of 72 male and 11 female recruits was performed. Bioelectrical impedance analysis (BIA) variables were: lean mass (LM), upper-extremity lean mass (UELM), trunk LM, lower-extremity lean mass (LELM), fat mass (FM), upper-extremity fat mass (UEFM), trunk FM, and lower-extremity fat mass (LEFM). Fitness tests included: vertical jump (VJ), peak anaerobic power (PAPw), 75-yard pursuit run (75PR), push-ups, sit-ups, 2-kg medicine ball throw (MBT), and the multi-stage fitness test (MSFT). Partial correlations and ANCOVAs between quartiles assessed relationships between body composition and performance. Significant moderate-to-large relationships were found; LM, UELM, trunk LM, LELM all related to PAPw (r = 0.500-0.558) and MBT (r = 0.494-0.526). FM, UEFM, trunk FM, LEFM all related to VJ (r = -0.481 to -0.493), 75PR (r = 0.533-0.557), push-ups (r = -0.484 to -0.503), sit-ups (r = -0.435 to -0.449), and MSFT (r = -0.371 to -0.423). The highest LM quartile (4) had superior PAPw and MBT than LM quartiles 1-3. Higher FM quartiles performed poorer in VJ, push-ups, and sit-ups. The 75PR quartiles 2, 3, and 4 were slower than quartile 1, and MSFT quartile 4 completed less shuttles. Total and segmental measures of LM and FM shared the same relationships; lower FM and higher LM related to better performance. Monitoring body composition could help guide training to optimize performance.

KEY WORDS: Fat-free mass, lean body mass, police officer, trainee, fitness, work capacity

INTRODUCTION

Law enforcement work can be a mixture of low-intensity activities interspersed with very demanding, arduous tasks such as sprinting, jumping, dragging, lifting, or using physical force to detain suspects (36). Furthermore, law enforcement officers have to carry additional load (including body armor) of around 10 kg when on-duty (3), which negatively impacts job task performance (13). The job requirements of policing dictate that law enforcement officers possess adequate upper and lower-body power, muscular endurance, cardiorespiratory fitness, and change-of-direction speed to complete occupational tasks effectively and safely (10, 23). Despite academy training classes typically having recruits with a range of physical abilities (28), law enforcement agencies must still properly train recruits and develop sufficient fitness to meet their specific occupational demands.

Power is the ability to generate great force in a short time and is a foundational characteristic for many dynamic actions, which for law enforcement officers might be jumping over obstacles or pursuing a suspect (16, 28). Lower-body power can be assessed with the vertical jump (VJ), and a lower VJ height can identify recruits that are more likely to experience an injury during academy training (34). Upper-body power is equally important for law enforcement officers, as they may physically engage with a suspect and need rapid force application with their arms (12, 28). The medicine ball throw (MBT) indirectly measures upper body power (5), and sex-differences in MBT distance has been demonstrated in law enforcement officer recruits (28). The 75-yard pursuit run (75PR) was created to simulate the linear and change-of-direction speed needed during a foot pursuit (29, 30). Recent literature has shown a faster 75PR time was significantly related to greater jumping ability, and faster linear and change-of-direction speed in men and women (36).

Muscular endurance is an important characteristic for officers performing repeated tasks such as running, pushing, and pulling (12, 24). Low repetitions of push-ups have been associated with increased risk for time-loss injury (19, 24). Like the push-ups, males that completed a lower number of repetitions in the 2-minute sit-up test were shown to be 1.6-1.9 times more likely to get injured than soldiers that complete a higher number of sit-ups in the test (19). Aerobic capacity is essential to the physical tasks required of the job (8), and may be most important in the recovery between bouts of extreme physical activity for replenishment of tissue oxygen, resynthesis of creatine phosphate, and clearance of lactate (15). The multi-stage fitness test (MSFT) has been extensively utilized and proven to be a reliable and valid measure of maximal aerobic capacity (31, 35), and recruits that graduate the academy exhibit much higher scores than those that did not (21).

Noting the importance of fitness to law enforcement recruits, body composition can influence fitness test performance, and a number of studies have investigated the effects and relationships body composition has with performance measures for law enforcement officers. Dawes et al. (12) conducted a retrospective study on the relationships between body composition (as measured by 3-site skinfold thickness) and physical performance in 76 male police officers. Estimated lean body mass (LM) positively correlated with push-ups (r = 0.444), bench press (r = 0.781), and VJ (r = 0.391) performance (12). Body fat mass (FM) negatively correlated with VJ performance (r = -0.369) and estimated oxygen consumption (r = -0.419) and positively correlated with 2.4-km run time (r = 0.399) (12). These findings highlight the importance of LM for officers and development of LM in recruits attending the academy. Further to this, more FM has been associated with fewer repetitions in tests of muscular endurance (push-ups [r = -0.461], sit-ups [r = -0.525], and pull-ups [r = -0.769]) and slower obstacle course time (r = 0.563) in part-time male Special Weapons and Tactics officers (11). Due to the impact of LM and FM for officers, accurately measuring body composition for recruits in the academy could provide vital information relating to fitness test potential and, by extension, job performance.

While there is current research on body composition and physical fitness in law enforcement recruits (11, 12), no known research has investigated segmental body composition of recruits and relationships to physical fitness performance measures. Given that common tests for law enforcement recruits are specific to upper body (push-ups, MBT), lower body (VJ, 75PR, and MSFT Shuttles), and trunk (sit-ups) musculature, it may be beneficial to identify any relationships between the bodily segments and related performance measures. Therefore, the purpose of this study was to investigate the relationships between whole and segmental body composition to physical fitness tests that are required of law enforcement recruits. It was hypothesized that higher FM would correlate with lower performance scores and higher LM would correlate with higher performance scores. Additionally, LM and FM for upper extremities (UELM and UEFM, respectively), lower extremities (LELM and LEFM, respectively), and trunk segments would show similar relationships to their body-part specific performance tests.

METHODS

Participants
Archival law enforcement recruit data were provided to the researchers for the purposes of conducting this study. The sample originally consisted of 91 recruits; however, eight recruits failed to complete all the performance testing or body composition analysis. This left a sample of 83 recruits (age = 27.31 ± 5.65 years; height = 1.73 ± 0.09 m; body mass = 82 ± 13.9 kg), consisting of 72 males (age = 27.22 ± 5.66 years; height = 1.75 ± 0.07 m; body mass = 85.03 ± 12.04 kg) and 11 females (age = 27.91 ± 5.82 years; height = 1.60 ± 0.05 m; body mass = 62.22 ± 7.67 kg). This sample of law enforcement officer recruits was reflective of law enforcement recruit classes in terms of ratio of males to females (27-30). This study was approved by the Institutional Review Board at California State University, Fullerton (HSR-17-18-370) and followed the recommendations of the Declaration of Helsinki (43). Additionally, this research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (32).

Protocol
A retrospective analysis was conducted on existing data collected from recruits belonging to an academy class prior to training. Relationships between body composition and fitness test performance were assessed with partial correlations, and differences between quartiles of LM and FM were assessed with multiple analyses of covariance (ANCOVA). Data in this study were collected by staff working for one US-based law enforcement agency during the Winter in 2017. Staff were all trained by a Tactical Strength and Conditioning Facilitator (certified through the NSCA) who verified their proficiency, and the procedures used for testing have been established in the literature (26-29). Testing occurred between 0900-1400 (9:00am-2:00pm) depending on recruit availability. Recruits typically did not eat in the 2-3 hours prior to their testing session as they were completing employee-specific documentation. It should be noted that hydration was not controlled for in the recruits, and this could influence the body composition data (6). Food

consumption was also not controlled, although recruits generally could not eat due to the administrative responsibilities (28, 29). These conditions, especially considering the body composition analysis, were not ideal. However, this could not be controlled for by the researchers due to the data being retrospective. It should also be noted that the data collection procedures were very typical for the real-world academy conditions (26-29).

Age, height, and body mass were recorded indoors for each recruit before the fitness testing. Height was measured using a portable stadiometer (Seca, Hamburg, Germany), and body mass was recorded by the InBody 720 (Biospace Co., Seoul, Korea), before the body composition analysis. Fitness tests were conducted outdoors on concrete or asphalt surfaces at the law enforcement agency training facility on a day scheduled by the agency staff. The temperature was consistent with the temperate, mild climate of southern California. Recruits wore their physical training attire (cotton t-shirt, shorts, and athletic sneakers) during the fitness tests. To complete the fitness tests, recruits rotated through the testing stations in small groups of 3-4. Recruits were allocated to a station before rotating to the next station when all groups were finished. The exception was the MSFT, which was completed last by all recruits in groups of 14-16.

Multifrequency BIA was performed with the InBody 720 (Biospace Co., Seoul, Korea) to estimate total and segmental body composition. Previous research has demonstrated the InBody 720 to be highly reliable in men and women (ICC = 0.97-0.98), and valid when compared to dual-energy x-ray absorptiometry (1, 20). Additionally, BIA has been suggested in law enforcement populations because of its practicality (29), and has been used in sport conditioning programs as a method of segmental body composition analysis (14). The test was administered by trained staff from InBody, done first in the testing session, and similar to previously established methods (2, 14, 38). Recruits were asked to remove any jewelry and metallic wear before their palms and soles were cleaned with an electrolyte tissue. Recruits then stood on the InBody scale with their soles in contact with the electrodes and body mass was measured by the device. Height, age, and sex was then manually entered into the display by trained staff. Next, recruits grasped hand electrodes with palms and fingers making contact, elbows extended and shoulders slightly abducted. The InBody 720 measured entire body composition of five segments (both arms, both legs, and trunk) (14). For analysis, body composition measures for both arms were added together for upper extremities, and both legs added together for lower extremities.

The VJ indirectly measured lower body power using a Vertec apparatus (Perform Better, Rhode Island, USA), and followed established assessment protocols (4, 7, 28, 33). Recruits first obtained a standing reach height and then jumped using a countermovement from a bilateral stance. VJ height was recorded in inches by subtracting the standing reach height from the peak jump height, and then converted to cm for analysis. Each recruit completed two trials, with a recovery time between trials of approximately 1-minute. The best trial result was used for analysis. Peak anaerobic power in watts (PAPw) was estimated using the equation from Sayers et al. (37): $\text{PAPw} = 60.7 \times (\text{VJ height [cm]}) + 45.3 \times (\text{body mass [kg]}) - 2055$.

Upper body muscular endurance was measured using a 1-minute maximal effort push-up test. Procedures followed previously established research protocols (7, 24, 29, 33), where all recruits began the test in the "up" position with body straight and hands positioned slightly wider than shoulder width. The exact hand width in the push-up was left to the personal preference for the recruit. A tester placed a fist on the floor directly under the recruit's chest to ensure they descended to an appropriate depth, and all female recruits were partnered with a female tester. The recruits performed as many correct push-ups as possible in the time allotted.

Trunk muscular endurance was measured with a 1-minute maximal effort sit-up test. Again, procedures followed previously established research protocols (7, 12, 24), and recruits began on their backs with their knees bent, heels flat on the ground, hands interlocked behind their heads, and a partner anchoring their feet. Recruits completed as many correct sit-ups as possible within the allotted time.

The MBT was used as an indirect measure of upper body power, and procedures adapted from existing research (28, 29). The recruits started the test in a seated position with their head, shoulders, and lower back up against a concrete wall, and legs extended perpendicularly against the ground. Using a two-handed chest pass, the recruits propelled a 2-kg medicine ball (Champion Barbell, Texas, USA) as far as possible without any part of the body moving away from the wall. The medicine ball was dusted with chalk to allow for better gripping by recruits, and to mark where the ball impacted the ground. A standard tape measure was used to measure from the nearest chalk mark to the wall. Two trials were completed with a rest time of approximately 60 s between trials. The best trial was used for analysis.

The 75PR was used to assess a simulated foot pursuit by a law enforcement officer (30). The recruit completed five, 12.1-meter (m), linear sprints around a square grid, integrated with four, 45° direction changes zig-zagging across the grid. Recruits were also required to negotiate over three barriers that were 2.44 m long and 0.15 m high that simulated road-side curbs during three of the five sprints (Figure 1). Time was recorded with a stopwatch from the initiation of movement at the start, until the recruit crossed the finish line. Timing with stopwatches is standard practice in law enforcement testing (4, 7, 24, 30), and testers trained in the use of stopwatch timing procedures can record reliable data (17).

The MSFT was used to measure maximal aerobic capacity in the recruits and was conducted on an asphalt surface. Recruits were required to run back and forth between two lines spaced exactly 20 m apart, which were indicated by markers. Completion of one lap between the two lines resulted in completion of one shuttle. The speed of running for this test was standardized by pre-recorded auditory cues (beeps) played from an iPad handheld device (Apple Inc., Cupertino, California) connected via Bluetooth to a portable speaker (ION Block Rocker, Cumberland, Rhode Island). This test started at 8.5 kilometers per hour (km/h), increasing by 0.5 km/h with each additional stage (a collection of seven or more shuttles), and was scored according to the final stage and shuttle the recruit achieved. The test was terminated when the recruit was unable to reach the next line twice in a row in accordance with the auditory cues.

Final scores by stage and shuttle were converted to total number of shuttles completed for analysis (29, 31, 35).

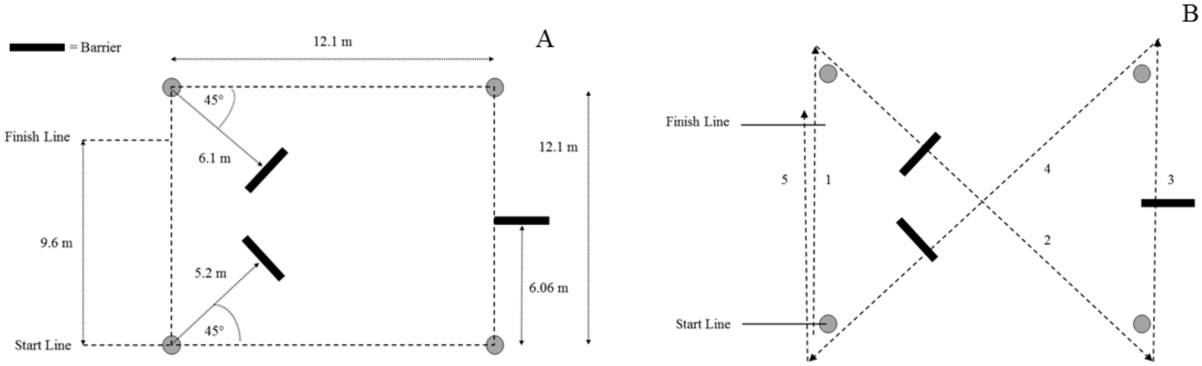

Figure 1. (A) The dimensions for the 75-yard pursuit run (75PR) in meters and (B) the running direction (numbered in order). The barriers were 2.44 m long and 0.15 m high.

Statistical Analysis
All data were entered into Microsoft Excel, before being transferred to the Statistics Package for Social Sciences (Version 26; IBM Corp., New York, USA) for statistical analyses. Descriptive statistics (mean ± standard deviation) were calculated for each variable, and then independent samples t-tests used to assess differences between male and female recruits. Effect sizes (d) were calculated for the between sex comparisons, where the difference between the means was divided by the pooled standard deviation (11). As previously established, a d less than 0.2 was considered a trivial effect; 0.2 to 0.6 a small effect; 0.6 to 1.2 a moderate effect; 1.2 to 2.0 a large effect; 2.0 to 4.0 a very large effect; and above 4.0 an extremely large effect (18). Additionally, a positive effect size indicated male scores were greater, and a negative effect size indicated female scores were greater. Sex was controlled for with correlations and analyses of variance since females generally have higher percent body fat and do not perform as well compared to their male counterparts (30). Partial correlations investigated the relationships between total and segmental body composition to the performance measures of the law enforcement recruits. Correlation (r) strength was defined as: an r between 0 to 0.3, or 0 to -0.3, considered small; 0.31 to 0.49, or -0.31 to -0.49, moderate; 0.5 to 0.69, or -0.5 to -0.69, large; 0.7 to 0.89, or -0.7 to -0.89, very large; and 0.9 to 1, or - 0.9 to - 1, near perfect relationship, in agreement with Hopkins (18). Recruits were then stratified into quartiles based on LM and FM with the lowest 25% in quartile 1, second lowest 25% in quartile 2, second highest 25% in quartile 3, and the highest 25% in quartile 4. This created groups of LM and FM from low-to-high, and ANCOVAs were used to assess differences in the groups for each of the performance measures. A Bonferroni post hoc adjustment was used for multiple pairwise comparisons. Levene's test for equality of variances were assessed for assumption of equal variances. Statistical significance for all tests was set at $p < 0.05$.

RESULTS

Descriptive statistics for the whole sample, males, and females are listed in Table 1. There were significant ($p < 0.001$) between-sex differences for all the variables except age, FM, UEFM, LEFM, sit-ups, and MSFT Shuttles. Equal variances were assumed for all variables except for trunk FM ($p < 0.042$; $d = 0.55$). This changed the results from non-significant to significant. Large to very large effect sizes were seen in the differences in height, body mass, LM, UELM, trunk LM, LELM, VJ, PAPw, 75PR, push-ups, and MBT.

Table 1. Descriptive statistics for anthropometrics, whole and segmental composition, and performance measures in male and female law enforcement recruits ($n = 83$).

	All (n = 83)	Males (n = 72)	Females (n = 11)	p-value	d
Age (y)	27.31 ± 5.65	27.22 ± 5.66	27.91 ± 5.82	0.710	-0.12
Height (m)	1.73 ± 0.09	1.75 ± 0.07	1.60 ± 0.05	<0.001	2.47
BM (kg)	82.00 ± 13.90	85.03 ± 12.04	62.22 ± 7.67	<0.001	2.26
LM (kg)	62.85 ± 10.44	65.59 ± 7.96	44.93 ± 6.11	<0.001	2.91
FM (kg)	19.15 ± 6.97	19.44 ± 7.25	17.29 ± 4.51	0.345	0.36
UELM (kg)	7.31 ± 1.50	7.72 ± 1.10	4.64 ± 0.85	<0.001	3.13
Trunk LM (kg)	28.16 ± 4.48	29.39 ± 3.24	20.06 ± 2.58	<0.001	3.19
LELM (kg)	18.33 ± 3.21	19.14 ± 2.52	13.01 ± 1.87	<0.001	2.76
UEFM (kg)	2.26 ± 1.24	2.27 ± 1.30	2.24 ± 0.76	0.943	0.03
Trunk FM (kg)	10.44 ± 4.05	10.69 ± 4.20	8.80 ± 2.40	0.042†	0.55
LEFM (kg)	5.15 ±1.63	5.15 ± 1.68	5.16 ± 1.35	0.975	-0.01
VJ (cm)	54.11 ± 12.35	56.05 ± 11.79	41.45 ± 7.77	<0.001	1.46
PAPw (W)	4944.31 ± 971.17	5198.68 ± 733.72	3279.39 ± 629.87	<0.001	2.81
75PR (s)	16.98 ± 0.95	16.82 ± 0.88	18.02 ± 0.77	<0.001	-1.45
Push-ups (reps)	45.40 ± 13.33	47.82 ± 12.00	29.55 ± 10.75	<0.001	1.60
Sit-ups (reps)	35.82 ± 10.22	35.96 ± 10.57	34.91 ± 7.94	0.753	0.11
MBT (m)	6.18 ± 1.12	6.47 ± 0.85	4.27 ± 0.71	<0.001	2.81
MSFT Shuttles	61.69 ± 17.98	61.67 ± 18.79	61.82 ± 12.03	0.979	-0.01

Note: Values for are expressed as means ± standard deviations. p-values are for t-tests. BM = body mass; LM = lean mass, FM = fat mass; UELM = upper extremity lean mass, LELM = lower extremity lean mass; UEFM = upper extremity fat mass, LEFM = lower extremity fat mass; VJ = vertical jump; PAPw = peak anaerobic power; 75PR = 75-yard pursuit run, MBT = medicine ball throw; MSFT = multi-stage fitness test. † Equal variances not assumed significance.

Partial correlations between anthropometrics, body composition, and the fitness performance measures are listed in Table 2. Total and segmental measures of LM (UELM, trunk LM, LELM) and FM (UEFM, trunk FM, LEFM) shared contrasting relationships with the performance tests. Specifically, measures of LM showed positive relationships ($p < 0.001$) with PAPw and MBT, and no significant relationships to the other performance tests. Measures of FM showed no relationship with PAPw or MBT but had significant negative relationships ($p < 0.001$) with VJ, push-ups, sit-ups, and MSFT shuttles, and a significant positive relationship ($p < 0.001$) with the 75PR.

Table 2. Partial correlations between whole and segmental body composition to performance tests in male and female law enforcement recruits (n = 83).

		Lean Mass				Fat Mass			
		LM	UELM	Trunk LM	LELM	FM	UEFM	Trunk FM	LEFM
VJ	r	-0.034	-0.044	-0.062	-0.054	-0.492	-0.481	-0.493	-0.492
	p	0.761	0.694	0.580	0.632	<0.001†	<0.001†	<0.001†	<0.001†
PAPw	r	0.558	0.547	0.543	0.500	0.082	0.056	0.099	0.039
	p	<0.001†	<0.001†	<0.001†	<0.001†	0.466	0.619	0.378	0.730
75PR	r	-0.038	0.017	0.021	-0.071	0.553	0.544	0.557	0.533
	p	0.736	0.881	0.854	0.524	<0.001†	<0.001†	<0.001†	<0.001†
Push-ups	r	-0.089	-0.095	-0.108	-0.057	-0.501	-0.492	-0.503	-0.484
	p	0.429	0.393	0.332	0.613	<0.001†	<0.001†	<0.001†	<0.001†
Sit-ups	r	0.050	-0.016	-0.013	0.056	-0.449	-0.446	-0.447	-0.435
	p	0.657	0.886	0.904	0.618	<0.001†	<0.001†	<0.001†	<0.001†
MBT	r	0.526	0.519	0.525	0.494	0.173	0.129	0.194	0.136
	p	<0.001†	<0.001†	<0.001†	<0.001†	0.120	0.249	0.081	0.222
MSFT Shuttles	r	-0.021	-0.150	-0.143	0.019	-0.418	-0.423	-0.423	-0.371
	p	0.855	0.179	0.201	0.863	<0.001†	<0.001†	<0.001†	<0.001†

Note: LM = lean mass, FM = fat mass; UELM = upper extremity lean mass, LELM = lower extremity lean mass; UEFM = upper extremity fat mass, LEFM = lower extremity fat mass; VJ = vertical jump; PAPw = peak anaerobic power; 75PR = 75-yard pursuit run, MBT = medicine ball throw; MSFT = multi-stage fitness test. † Significant (p < 0.01) relationship between the two variables.

Differences in quartile groups based on LM are detailed in Table 3. For PAPw, quartile 4 (highest LM) was significantly higher than quartiles 1 (lowest LM; $p = 0.005$) and 2 (second highest LM; $p = 0.001$). For the MBT, quartile 4 was significantly higher than quartiles 1 ($p < 0.001$), 2 ($p = 0.015$), and 3 ($p = 0.036$). Differences in quartile groups based on FM are listed in Table 4. For the VJ, quartiles 4 (highest FM; $p < 0.001$) and 3 (second highest FM; $p < 0.001$) had significantly lower jump height than quartile 1 (lowest FM). For the 75PR, quartiles 2 (second lowest; $p = 0.006$), 3 ($p < 0.001$), and 4 ($p < 0.001$) were each significantly slower than quartile 1. The push-up test showed quartiles 3 ($p = 0.005$) and 4 ($p < 0.001$) performed significantly less repetitions than quartile 1, and quartile 4 ($p = 0.005$) performed significantly less repetitions than quartile 2. For the sit-ups, quartiles 3 ($p = 0.01$) and 4 ($p < 0.001$) performed significantly less repetitions than quartile 1. Lastly, for the MSFT, quartile 4 completed significantly fewer shuttles than both quartiles 1 ($p = 0.005$) and 2 ($p = 0.037$).

Table 3. (Mean ± SE; 95% CI) Quartiles based on LM compared with performance tests with sex as a covariate.

	Quartile 1 (*n* = 19) LM = 35.10-57.7	Quartile 2 (*n* = 22) LM = 57.8-63.6	Quartile 3 (*n* = 21) LM = 63.7-69.3	Quartile 4 (*n* = 21) LM = 69.4-90.0
VJ	56.58 ± 3.57 (49.48-63.69)	53.44 ± 2.56 (48.34-58.54)	54.03 ± 2.62 (48.82-59.24)	52.66 ± 2.62 (47.45-57.87)
PAPw	4550.59 ± 202.76 (4146.93-4954.24)	4708.77 ± 145.48 (4419.14-4998.39)	4994.57 ± 148.64 (4698.64-5290.49)	5497.06 ± 148.64 (5201.14-5792.98) a b
75PR	17.26 ± 0.27 (16.73-17.8)	16.93 ± 0.19 (16.55-17.32)	16.72 ± 0.2 (16.33-17.11)	17.05 ± 0.20 (16.66-17.44)
Push-ups	42.41 ± 3.58 (35.29-49.53)	46.67 ± 2.57 (41.56-51.78)	50.51 ± 2.62 (45.29-55.73)	41.65 ± 2.62 (36.43-46.88)
Sit-ups	29.68 ± 3.13 (23.45-35.90)	39.71 ± 2.24 (35.24-44.17)	36.56 ± 2.29 (31.99-41.12)	36.56 ± 2.29 (31.99-41.12)
MBT	5.43 ± 0.23 (4.97-5.89)	6.15 ± 0.17 (5.82-6.48)	6.21 ± 0.17 (5.87-6.54)	6.86 ± 0.17 (6.52-7.19) a b c
MSFT Shuttles	53.52 ± 5.49 (42.59-64.45)	63.45 ± 3.94 (55.61-71.29)	69.6 ± 4.03 (61.59-77.62)	59.32 ± 4.03 (51.3-67.33)

Note: a = Significantly different ($p < 0.05$) from Quartile 1; b = Significantly different ($p < 0.05$) from Quartile 2; c = Significantly different ($p < 0.05$) from Quartile 3.

Table 4. (Mean ± SE; 95% CI) Quartiles based on FM compared with performance tests with sex as a covariate.

	Quartile 1 (*n* = 20) FM = 5.20-13.7	Quartile 2 (*n* = 21) FM = 13.8-19.6	Quartile 3 (*n* = 21) FM = 19.7-23.4	Quartile 4 (*n* = 21) FM = 23.5-39.7
VJ	63.50 ± 2.22 (59.09-67.91)	55.15 ± 2.22 (50.73-59.56)	49.94 ± 2.16 (45.63-54.24) a	48.32 ± 2.18 (43.98-52.65) a
PAPw	5042.52 ± 159.93 (4724.12-5360.91)	4898.13 ± 160.17 (4579.26-5217.01)	4695.01 ± 156.15 (4383.15-5005.87)	5146.28 ± 157.22 (4833.28-5459.27)
75PR	16.21 ± 0.17 (15.88-16.54)	17.02 ± 0.17 (16.69-17.36) a	17.21 ± 0.16 (16.88-17.53) a	17.45 ± 0.16 (17.13-17.78) a
Push-ups	52.67 ± 2.34 (48.01-57.33)	49.83 ± 2.34 (45.17-54.50)	41.27 ± 2.28 (36.71-45.81) a	38.17 ± 2.30 (33.59-42.75) a b
Sit-ups	42.98 ± 2.09 (38.83-47.14)	36.80 ± 2.09 (32.64-40.96)	33.54 ± 2.04 (29.48-37.60) a	30.30 ± 2.05 (26.21-34.38) a
MBT	6.07 ± 0.19 (5.69-6.44)	6.15 ± 0.19 (5.78-6.53)	6.20 ± 0.19 (5.83-6.57)	6.28 ± 0.19 (5.91-6.65)
MSFT Shuttles	68.56 ± 3.80 (60.99-76.13)	65.36 ± 3.81 (57.78-72.94)	63.04 ± 3.71 (55.65-70.43)	50.11 ± 3.74 (42.67-57.55) a b

Note: a = Significantly different ($p < 0.05$) from Quartile 1; b = Significantly different ($p < 0.05$) from Quartile 2; c = Significantly different ($p < 0.05$) from Quartile 3.

DISCUSSION

This study adds to existing literature on the importance of measuring body composition in law enforcement recruits, and development of LM while minimizing FM. Additional data is provided for future comparison regarding the segmental body composition of law enforcement recruits, and relationships were examined between measures of whole and segmental body composition to fitness performance tests common to law enforcement training. In general, the recruits with higher amounts of FM performed poorer in the VJ, 75PR, push-ups, sit-ups, and MSFT, and recruits with higher LM had a better PAPw and MBT. The first hypothesis was partially supported, as greater FM was associated with lesser lower body power, change-of-direction speed, upper and lower-body muscular strength and endurance, and cardiorespiratory fitness. To a lesser extent this was true for LM, as it related to greater lower and upper body power. The quartile analysis of LM and FM provided a more detailed examination of these relationships. The second hypothesis was not accepted as there were no differences in the relationships of whole-body and segmental measures of LM and FM. For example, FM showed a significant negative correlation with VJ, and all the segmental measures (UEFM, trunk FM, and LEFM) followed suit. It was thought that differences may exist because the amount of lean and fat mass in a segment could influence the related test performance. However, it may be simply that segments, as smaller parts of the whole-body, share similar relationships to performance tests.

Though intuitive, this sample of male recruits displayed a significantly higher body mass, and measures of LM (UELM, trunk LM, and LELM) compared to their female counterparts. Although this study did not assess body fat percentage, women shared similar measures of FM (less trunk FM) as the men and had significantly less LM which would indicate a higher percentage of body fat. This confirmed previous literature in regards to body composition in law enforcement officers (9, 40). Very large effect sizes (d = 2.76-3.19) were found for the higher amounts of LM in males compared to females, whereas the values of UEFM and LEFM were nearly identical with nonsignificant effect sizes.

Measures of FM showed negative relationships with VJ but not with PAPw, and LM relationships were the inverse with positive relationships to PAPw but not VJ. Fat tissue does not mechanically contribute to physical performance (aside from events where increased overall mass is important), so higher FM should be detrimental to jumping tasks. However, as the calculation of PAPw incorporates VJ height and body mass into the equation (37), a greater body mass could increase the derived PAPw scores. These relationships may be partially explained by LM, as the active muscle contributed to the jump height and body mass at the same time; FM can only contribute to body mass (and not performance). For LM, PAPw was significantly higher in quartile 4 than quartiles 1 and 2, further indicating lower-body power was maximized with increased LM, but not actual VJ height. With regards to upper-body power, there was a positive relationship between LM and MBT distance. In the LM quartiles, MBT increased with LM, but the differences were not significant until the 4th quartile. While the results of this study are slightly higher, Lockie et al. (28) found similar differences and effect sizes in the VJ (d = 1.50), PAPw (d = 2.12), and MBT (d = 2.68). Overall, this study showed LM related to upper and lower body power, and FM had detrimental effects on actual VJ height. This further demonstrates the importance of body composition in developing the physical characteristics needed to perform a job in law enforcement.

Results from the 75PR showed no relationship with LM, and a positive relationship with FM indicating it slowed time to completion. The 75PR was perhaps the most sensitive to FM changes in the quartile analysis, as quartiles 2, 3, and 4 were significantly slower than quartile 1. Negotiating the 75PR requires speed and rapid changes of direction, and small increases in FM could be detrimental to time. These results corresponded with previous studies were researchers concluded that higher body fat and greater waist circumference measures showed slower completion time of the 75PR (22, 29). Lockie et al. (22) found small correlations between the 75PR and muscle mass percent (r = -0.208) and FM percent (r = 0.220), detailing the detrimental effects of higher body fat to 75PR performance. Additionally, the quartile analysis of FM percent from Lockie et al. (22) was very similar to the quartile analysis of this study, showing a linear decrease in performance as FM increased. It is important to note this study used absolute measures of mass instead of percentages. Recently, Post et al. (36) assessed the relationships between the 75PR and measures of linear speed and change-of-direction ability in 21 men and 22 women age-matched to academy recruits. The 75PR showed significant relationships to the 5 m and 20 m sprint intervals, VJ, standing broad jump, Illinois agility test, and the 505 change-of-direction test. This highlighted characteristics that contributed to 75PR performance, and could develop law enforcement recruit's ability for foot pursuit (36).

The only performance tests that were not different between male and female recruits were the sit-ups and the MSFT shuttles. Partial correlations for push-ups, sit-ups, and MSFT shuttles showed no significant relationships with LM, and following suit, no difference existed for the push-ups, sit-ups, and MSFT shuttles in the quartiles based on LM. Though not significant, it is interesting that the greatest number of push-ups occurred in quartile 3 of LM and the greatest number of sit-ups occurred in quartile 2 of LM, which could reflect an optimal amount of LM for performance and warrants further investigation. Partial correlations for FM showed significant negative relationships with push-ups, sit-ups, and MSFT shuttles. For the quartiles, and similar to the VJ and 75PR, higher amounts of FM showed to be detrimental to the push-ups, sit-ups, and MSFT shuttles. Specifically, quartiles 3 and 4 had significantly poorer performance in the push-ups and sit-ups, and only the 4th quartile had a significant drop in MSFT shuttles completed. For performance tests related more to muscular endurance, the presence of more LM did not show improved results; it was the reduced amount of FM that related to improved performance. This adds support to previous research that found similar results of reduced performance in the push-ups, sit-ups, and MSFT shuttles with greater FM (22). The MSFT is a test of aerobic fitness and predictor of maximal oxygen consumption and relies heavily on the lungs and circulatory system for performance. While the presence of FM seems detrimental to MSFT shuttles overall, there may be more complex interactions that contribute to overall aerobic performance such as individual running technique and high-intensity running capability (22, 26). Regardless, minimizing FM is paramount to improving the aerobic fitness of law enforcement recruits.

Using BIA to screen and track FM and LM in recruits is important for law enforcement agencies given the relationship of body composition to fitness and performance. Due to the length of training academies (sometimes up to 27 weeks) (25), tracking body composition could provide evidence the recruit class is responding favorably to training, and therefore good training practice (7). Conversely, it may highlight that unfavorable changes are taking place and could inform the staff to change the priorities of the training program (22). Benefits of single frequency BIA are the devices are small, inexpensive, easy to operate (1), and have shown good validity and reliability in healthy adult populations (39). A similar device was used by Lockie et al. (22) in a retrospective analysis of 338 law enforcement recruits, where greater muscle mass and lesser FM related to better fitness performance, providing evidence for the use of cost-effective BIA devices in large recruit training classes. Multifrequency BIA devices have been used in numerous body composition studies (1, 20, 41), and while more expensive and less portable, provide detailed measures such as FM, total body water, LM, muscle mass, and segmental composition (1, 22). Cost of equipment for recruit training is a major consideration for agencies (22), but regardless of the choice, single or multifrequency BIA devices are effective tools for tracking body composition.

Training studies for law enforcement seem to be limited, but with the appropriate application of physical conditioning LM can be increased or maintained and FM decreased. Cocke et al. (7) compared two 6-month training study and found the randomized training program was superior to the periodized program in terms of reducing body mass, FM, and increasing LM. While both training groups saw improvements, the randomized program also showed better results with the 1-repetition maximum bench press, VJ, PAPw, and 2.4-km run time (7). A similar training study was conducted over the course of a 16-week academy, and found significant changes in upper and lower-body power, push-ups, sit-ups, change-of-direction speed, and half-mile shuttle run (9). Interestingly, while performance variables improved during the first half and whole 16 weeks, none of the variables improved during the second half of the study (9), indicating the occurrence of a plateau or ceiling effect.

The ability to specifically alter LM and FM as separate entities is noted in the discrete associations between these measures and specific fitness tests. As such BIA devices may be useful to inform which training programs are best to preserve or increased LM and/or decrease FM to improve specific test performance outcomes. For example, a program to increase LM may be appropriate for a recruit needing to improve MBT, while a decrease in FM may be appropriate for improving VJ performance. Additionally, relationships between body composition and performance measures may change over the course of academy training and monitoring how those relationships change across different phases of training would be useful to guide physical conditioning programming. While it has been recommended that BIA devices are more sensitive to changes from training when interpreting total body composition over segmental composition (38), future research could compare total and segmental body composition of recruits to existing officers at different points in their careers.

Despite the interesting findings, there are limitations to this study worth considering. This study used absolute measures of LM and FM, instead of relative percentage which may have yielded different results. Although indicative of a law enforcement academy training class (26-29), the sample size between males (n = 72) and females (n = 11) was not equal which can lead to unequal variances and reduced statistical power. It also should be noted that the recruit testing data were collected in the field, which is less controlled than a laboratory setting. Nonetheless, within the context of these limitations, the research has a high translation to practice given that the field outcome measures were those of a pragmatic nature for law enforcement populations.

Results from this study adds more understanding to the intersection of LM and FM and relationships with performance of law enforcement officer recruits. In general terms, lower levels of FM and higher LM among recruits appear to favor better performance on fitness tests. Since these tests are reflective of job task performance it is likely these same relationships would be observed when performing occupational tasks that require these underlying attributes. Decreasing FM while preserving or preferably increasing LM should be a focus of the training academy to improve overall test performance. Additionally, specific methods of training could partially follow the physical traits needed for the job (power, endurance, aerobic capacity, etc.) while targeting and monitoring the lean and fat tissue of the recruits. In-depth, segmental body composition analysis may be important. However, obtaining an estimation of whole-body LM and FM may be just as telling in relation to recruit performance while being easier and more cost-effective to perform.

ACKNOWLEDGEMENTS

This research project received no external financial assistance. None of the authors have any conflict of interest. The authors would like to thank the training instructors for facilitating this research, and the California State University, Fullerton tactical research team for collating the data.

REFERENCES

1. Aandstad A, Holtberget K, Hageberg *R*, Holme I, Anderssen SA. Validity and reliability of bioelectrical impedance analysis and skinfold thickness in predicting body fat in military personnel. Mil Med 179(2): 208-217, 2014.

2. Antonio J, Kenyon M, Ellerbroek A, Carson C, Burgess V, Tyler-Palmer D, Mike J, Roberts J, Angeli G, Peacock C. Comparison of dual-energy x-ray absorptiometry (DXA) versus a multi-frequency bioelectrical impedance (InBody 770) device for body composition assessment after a 4-week hypoenergetic diet. J Funct Morphol Kinesiol 4(2): 23, 2019.

3. Baran K, Dulla J, Orr RM, Dawes J, Pope RR. Duty loads carried by la sheriff's department deputies. J Aust Strength Cond 26(5): 34-38, 2018.

4. Beck AQ, Clasey JL, Yates JW, Koebke NC, Palmer TG, Abel MG. Relationship of physical fitness measures vs. occupational physical ability in campus law enforcement officers. J Strength Cond Res 29(8): 2340-2350, 2015.

5. Beckham G, Lish S, Keebler L, Longaker C, Disney C, DeBeliso M, Adams KJ. The reliability of the seated medicine ball throw for distance. J Phys Act Res 4(2): 131-136, 2019.

6. Burns RD, Fu Y, Constantino N. Measurement agreement in percent body fat estimates among laboratory and field assessments in college students: Use of equivalence testing. PLOS ONE 14(3): e0214029, 2019.

7. Cocke C, Dawes J, Orr RM. The use of 2 conditioning programs and the fitness characteristics of police academy cadets. J Athl Train 51(11): 887-896, 2016.

8. Collingwood TR, Hoffman *R*, Smith J. Underlying physical fitness factors for performing police officer physical tasks. Police Chief 71(3): 32-38, 2004.

9. Crawley AA, Sherman RA, Crawley WR, Cosio-Lima LM. Physical fitness of police academy cadets: Baseline characteristics and changes during a 16-week academy. J Strength Cond Res 30(5): 1416-1424, 2016.

10. Dawes JJ, Lindsay K, Bero J, Elder C, Kornhauser C, Holmes R. Physical fitness characteristics of high vs. Low performers on an occupationally specific physical agility test for patrol officers. J Strength Cond Res 31(10): 2808-2815, 2017.

11. Dawes J, Orr RM, Elder C, Rockwell C. Association between body fatness and measures of muscular endurance among part-time swat officers. J Aust Strength Cond 22(4): 33-37, 2014.

12. Dawes JJ, Orr RM, Siekaniec CL, Vanderwoude AA, Pope *R*. Associations between anthropometric characteristics and physical performance in male law enforcement officers: A retrospective cohort study. Ann Occup Environ Med 28(1): 26, 2016.

13. Dempsey PC, Handcock PJ, Rehrer NJ. Impact of police body armour and equipment on mobility. Appl Ergon 44(6): 957-961, 2013.

14. Esco MR, Snarr RL, Leatherwood MD, Chamberlain NA, Redding ML, Flatt AA, Moon JR, Williford HN. Comparison of total and segmental body composition using dxa and multifrequency bioimpedance in collegiate female athletes. J Strength Cond Res 29(4): 918-925, 2015.

15. Glaister M. Multiple sprint work. Sports Med 35(9): 757-777, 2005.

16. Haff GG, Nimphius S. Training principles for power. Strength Cond J 34(6): 2-12, 2012.

17. Hetzler RK, Stickley CD, Lundquist KM, Kimura IF. Reliability and accuracy of handheld stopwatches compared with electronic timing in measuring sprint performance. J Strength Cond Res 22(6): 1969-1976, 2008.

18. Hopkins WG. A scale of magnitude for effect statistics. 2013 [November 20th, 2020]. Retrieved from: https://www.sportsci.org/resource/stats/effectmag.html.

19. Knapik JJ, Sharp MA, Canham-Chervak M, Hauret K, Patton JF, Jones BH. Risk factors for training-related injuries among men and women in basic combat training. Med Sci Sports Exerc 33(6): 946-954, 2001.

20. Kukic F, Dopsaj M, Dawes J, Orr *R*, Cvorovic A. Use of human body morphology as an indication of physical fitness: Implications for police officers. Int J Morphol 36(4): 1407-1412, 2018.

21. Lockie RG, Balfany K, Bloodgood AM, Stierli M, Dulla JM, Dawes JJ, Orr RM. Change-of-direction speed and aerobic fitness could influence academy graduation in law enforcement recruits. In *Proceedings of the 2018 Australian Strength and Conditioning Association International Conference on Applied Strength and Conditioning*. 2018: Sydney, Australia.

22. Lockie RG, Carlock BN, Ruvalcaba TJ, Dulla JM, Orr RM, Dawes JJ, McGuire MB. Skeletal muscle mass and fat mass relationships with physical fitness test performance in law enforcement recruits before academy. J Strength Cond Res 35(5): 1287-1295, 2021.

23. Lockie RG, Dawes JJ, Balfany K, Gonzales CE, Beitzel MM, Dulla JM, Orr RM. Physical fitness characteristics that relate to work sample test battery performance in law enforcement recruits. Int J Environ Res Public Health 15(11): 2477, 2018.

24. Lockie RG, Dawes JJ, Kornhauser CL, Holmes RJ. Cross-sectional and retrospective cohort analysis of the effects of age on flexibility, strength endurance, lower-body power, and aerobic fitness in law enforcement officers. J Strength Cond Res 33(2): 451-458, 2019.

25. Lockie RG, Dawes JJ, Maclean ND, Pope RP, Holmes RJ, Kornhauser CL, Orr RM. The impact of formal strength and conditioning on the fitness of law enforcement recruits: A retrospective cohort study. Int J Exerc Sci 13(4): 1615-1629, 2020.

26. Lockie RG, Dawes JJ, Moreno MR, Cesario KA, Balfany K, Stierli M, Dulla JM, Orr RM. Relationship between the 20-m multistage fitness test and 2.4-km run in law enforcement recruits. J Strength Cond Res 35(10): 2756-2761, 2019.

27. Lockie RG, Dawes JJ, Moreno MR, McGuire MB, Ruvalcaba TJ, Bloodgood AM, Dulla JM, Orr RM. We need you: Influence of hiring demand and modified applicant testing on the physical fitness of law enforcement recruits. Int J Environ Res Public Health 17(20): 7512, 2020.

28. Lockie RG, Dawes JJ, Orr RM, Stierli M, Dulla JM, Orjalo AJ. An analysis of the effects of sex and age on upper- and lower-body power for law enforcement agency recruits before academy training. J Strength Cond Res 32(7): 1968-1974, 2018.

29. Lockie RG, Ruvalcaba TR, Stierli M, Dulla JM, Dawes JJ, Orr RM. Waist circumference and waist-to-hip ratio in law enforcement agency recruits: Relationship to performance in physical fitness tests. J Strength Cond Res 34(6): 1666-1675, 2020.

30. Lockie RG, Stierli M, Cesario KA, Moreno MR, Bloodgood AM, Orr RM, Dulla JM. Are there similarities in physical fitness characteristics of successful candidates attending law enforcement training regardless of training cohort? J Trainol 7(1): 5-9, 2018.

31. Moreno MR, Lockie RG, Kornhauser CL, Holmes RJ, Dawes JJ. A preliminary analysis of the relationship between the multistage fitness test and 300-m run in law enforcement officers: Implications for fitness assessment. Int J Exerc Sci 11(4): 730-738, 2018.

32. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1): 1-8, 2019.

33. Orr R, Dawes JJ, Pope *R*, Terry J. Assessing differences in anthropometric and fitness characteristics between police academy cadets and incumbent officers. J Strength Cond Res. Published Ahead of Print: doi:10.1519/JSC.0000000000002328, in press.

34. Orr R, Pope *R*, Peterson S, Hinton B, Stierli M. Leg power as an indicator of risk of injury or illness in police recruits. Int J Environ Res Public Health 13(2): 237, 2016.

35. Paradisis GP, Zacharogiannis E, Mandila D, Smirtiotou A, Argeitaki P, Cooke CB. Multi-stage 20-m shuttle run fitness test, maximal oxygen uptake and velocity at maximal oxygen uptake. J Hum Kinet 41(1): 81-87, 2014.

36. Post BK, Dawes JJ, Lockie RG. Relationships between tests of strength, power, and speed and the 75-yard pursuit run. J Strength Cond Res. In press. Published ahead of print.

37. Sayers SP, Harackiewicz DV, Harman EA, Frykman PN, Rosenstein MT. Cross-validation of three jump power equations. Med Sci Sports Exerc 31(4): 572-577, 1999.

38. Schoenfeld BJ, Nickerson BS, Wilborn CD, Urbina SL, Hayward SB, Krieger J, Aragon AA, Tinsley GM. Comparison of multifrequency bioelectrical impedance vs. dual-energy x-ray absorptiometry for assessing body composition changes after participation in a 10-week resistance training program. J Strength Cond Res 34(3): 678-688, 2020.

39. Vasold KL, Parks AC, Phelan DM, Pontifex MB, Pivarnik JM. Reliability and validity of commercially available low-cost bioelectrical impedance analysis. Int J Sport Nutr Exerc Metab 29(4): 406-410, 2019.

40. Violanti JM, Ma CC, Fekedulegn D, Andrew ME, Gu JK, Hartley TA, Charles LE, Burchfiel CM. Associations between body fat percentage and fitness among police officers: A statewide study. Saf Health Work 8(1): 36-41, 2017.

41. Vuković M, Kukić F, Čvorović A, Janković D, Prćić I, Dopsaj M. Relations between frequency and volume of leisure-time physical activity and body composition in police officers. Res Q Exerc Sport 91(1): 47-54, 2020.

42. World Medical Association. World Medical Association Declaration of Helsinki. Recommendations guiding physicians in biomedical research involving human subjects. JAMA 277(11): 925-926, 1997.