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Original Research

Comprehensive Fitness Assessment in a Professional Military Education Cohort: A Cross-Sectional Study

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Abstract

International Journal of Exercise Science 18(8): 811-835, 2025. https://doi.org/10.70252/WUPH8495 Military personnel face rigorous physical and cognitive demands critical for operational readiness and long-term health. This study evaluated body composition, cognitive performance, and physical fitness metrics in non-entry-level service members to inform tailored fitness interventions. This cross-sectional study analyzed data from Air Command Staff College personnel (N = 307; 89 females, 218 males; age: 37 ± 5 years) at Air University, Maxwell Air Force Base. Participants completed assessments for body composition (body mass index [BMI], body fat percentage [%BF], fat mass index [FMI], fat-free mass index [FFMI]), flexibility (sit-and-reach test, functional reach test), cognitive performance (cognitive reaction time), power (countermovement jump), strength (grip strength, isometric midthigh pull), muscular endurance (plank), and aerobic fitness (Estimated VO_{2max}). Relationships between age, sex, and fitness variables were analyzed with regression models, with percentile ranking, and comparisons to the American College of Sports Medicine (ACSM) guidelines. Age-related increases in BF% ($r = 0.116$, $p = 0.045$) and FMI ($r = 0.129$, $p = 0.025$) were observed, alongside declines in muscular strength, power, and endurance (all $p < 0.01$). Females exhibited higher BF% and FMI, while males had greater FFMI and strength. Older participants had lower compliance with ACSM standards, indicating elevated health risks. Targeted interventions should address age- and sex-specific needs, focusing on preserving lean mass, strength, and cognitive agility. Baseline fitness data contributes to designing evidence-based programs that enhance long-term readiness and operational performance.

Keywords: Tactical athlete, physical fitness standards, aerobic capacity, muscular endurance, body composition

Introduction

Military personnel are required to meet high physical and cognitive demands to support combat and occupational readiness. This is important on the battlefield and for maintaining long-term health post-service.[1] Achieving optimal physical readiness is essential for reducing injury risks, enhancing operational ability, and supporting overall well-being.[2,3] Daily physical demands for military personnel include sustained standing, running and marching, lifting heavy objects, and loaded carries. Consequently, a high level of health-related (aerobic fitness, body composition, flexibility, muscular strength, and muscular endurance) and skill-related (coordination, power, reaction time) components of physical fitness are required.[4] Routine fitness assessments are standard across military branches typically emphasizing aerobic capacity and muscular endurance, neglecting key dimensions such as agility, cognitive response, and flexibility that are vital for combat-specific roles.[4] These demands evolve as mid- to senior-level military officers progress through their careers. Leadership responsibility, interpersonal demands, and cognitive workload typically increase with rank, while daily physical demands may decrease.[5] Mid-level officers may also be dealing with the results of prior injuries that often unreported. Consequently, this military sub-population may focus less on their personal fitness and health. Assessing diverse fitness domains provides insight into the current health and performance status of mid- to senior-level military officers and Department of Defense (DOD)-contracted civilians. It supports the development and refinement of individualized interventions aligned with health-oriented readiness, long-term operational capacity, and life after service.[6]

Fitness assessment standards are often designed to either compare individuals within a peer group or evaluate them against established health and performance benchmarks.[7,8] Norm-referenced data rank an individual’s fitness and health measures relative to a representative sample of peers which can be further compared by age group and gender. A limitation of normative reference data is that it provides a comparative but not inherently meaningful measure of health or occupational performance.[9] While normative reference data may not directly indicate health or performance thresholds, they allow for meaningful comparisons between individuals or subgroups, providing context for how military personnel's fitness levels align with broader population trends or specific groups (e.g., age, sex). This can help identify relative strengths and weaknesses, which are useful for tailoring interventions or assessing changes over time. There remains a lack of readily available data in the literature, especially for non-entry level service members, providing a wider range of health- and skill-related fitness assessment outcomes across a diverse military population within the United States.

Criterion referenced data can provide benchmarks tied to health and readiness outcomes. The American College of Sports Medicine (ACSM) guidelines establish age and sex-specific categorizations serving as evidence-based thresholds for fitness that may correlate with changes to risks of cardiovascular disease and all-cause mortality highlighting the role of aerobic and muscular fitness as protective health factors.[10] Meeting these thresholds is critical for service members, as adequate fitness levels support not only personal health but also operational readiness.[11,12] Achieving a specific level of cardiorespiratory fitness or meeting muscular strength criteria may indicate a lower likelihood of cardiovascular complications thereby linking fitness outcomes directly to both health and mission preparedness.[13]

Recent military fitness programs highlight an increasing shift toward multidisciplinary approaches to military readiness. Examples include the United States Army's Holistic Health and Fitness and Comprehensive Soldier Fitness, the U.S. Air Force's (USAF) Comprehensive Airmen Fitness, Operational Support Teams, Optimizing the Human Weapon System, and

Comprehensive Readiness for Aircrew Flying Training, the Space Force's Holistic Health Approach, and the Navy's Human Performance program, STRIKE. These initiatives recognize that true fitness extends beyond physical endurance, underlining cognitive resilience and adaptability as essential components of readiness. Data that quantifies these diverse fitness dimensions remains limited, particularly among mid-career military personnel across service branches and DOD-contracted civilians.

The USAF's new BOLT Program is a USAF-led initiative developed to support the health, performance, and readiness for military personnel at Air University on Maxwell Air Force Base; encompassing mental, spiritual, physical, and social aspects. The USAF Air University enrolls officers from multiple U.S. service branches—including the Army, Marine Corps, Navy, and Space Force—as well as international military officers and DOD-civilian faculty/staff. The BOLT program includes structured assessments across physical, cognitive, and wellness domains to guide the development of Tailored Performance Plans (TPPs) which are individualized strategies designed to enhance performance and long-term well-being in line with the USAF's Comprehensive Airmen Fitness program[14] and Total Force Fitness principles.[15,16]

This study seeks to assess a wide range of pre-BOLT program baseline metrics for health, fitness and cognition across a broad USAF cohort. Relationships between age, sex, and baseline metrics were evaluated to identify key trends and predictors of readiness, with percentile rankings calculated to provide preliminary within-sample norms and comparisons to ACSM guidelines offering actionable benchmarks and relatable goals for operational fitness tailored to Airmen and Command. This study aimed to assess foundational physical and cognitive fitness domains relevant to long-term health and operational support capacity in mid-career military professionals. We hypothesized that: (1) age would be negatively associated with body composition and performance-based metrics; and (2) that a substantial proportion (≥50%) of participants would fall below "recommended" ACSM fitness thresholds defined as "Poor" or "Very Poor," with those in older age groups scoring lower. The goal was to provide the USAF with a broad assessment of military fitness within the Air Command and Staff College (ACSC) students, faculty and staff, as well as provide baseline measures to be used to develop and evaluate new programs designed to improve Airman health and wellness. This work will support and grow the existing body of literature aimed at developing military fitness standards in response to the complex demands of service and guide future fitness initiatives and readiness assessments within military settings.

Methods

Participants

Members of the ACSC at Air University, Maxwell Air Force Base (N = 307, females = 89, males = 218), age (37 ± 5 years), height (173.94 ± 10.04 cm), and body mass (83.34 ± 16.27 kgs) took part in the screening. Among these participants, 18 were non-military DOD-civilian faculty or instructors (N = 18, females = 8, males = 10, age = 48 ± 11 years). The youngest (24 years) and oldest (64 years) participants were both part of this DOD-civilian group. Including non-military DOD-civilian faculty and instructors provided a more comprehensive assessment of the ACSC population, capturing the full range of age and experience within a shared academic and occupational environment. Several DOD-civilian participants were known to be prior service members, offering additional insight into physical health outcomes later in the military lifecycle. Inclusion of the faculty and staff contributes to a broader understanding of health and performance trends after active service. Moreover, their instructional and leadership roles within military education, and frequent collaboration with field-grade officers, reflect the integrated nature of military and civilian personnel in sustaining mission readiness. No formal *a priori* power analysis was conducted, as the sample size was determined by the number of available students and faculty at ACSC who consented to participate. However, a post hoc power analysis for multiple linear regression with three predictors (Age, Sex, and an Interaction term) demonstrated a power level of 0.99998 to detect a medium effect size (f^2=0.15), indicating that the sample size was more than sufficient for the analyses conducted. The large sample size was also adequate for the bivariate analysis. The screening was conducted during the first six weeks of the 10-month program. Participants completed one testing session, including body composition, sit-and-reach test, functional reach test, functional movement screen (FMS) pain provocation tests, cognitive assessment, vertical jump, grip strength, isometric mid-thigh pull, forearm plank, and six-minute run/walk test. The FMS pain provocation assessments were completed first to ensure the screening would not cause pain or injury. No participant was eliminated from the screening due to pain from these tests and results are not included below. Each participant read and signed the informed consent approved by the university and Air Force Institutional Review Boards (IRB # 24-877 EP 240) before any assessments took place. This research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science*.[17]

Protocol

Body composition assessment.

Height was assessed using a Seca stadiometer (SECA, Hamburg, Germany). Weight and body composition were measured using a bioelectrical impedance analysis (BIA) via the TANITA 568 Segmental Body Composition Analyzer (Tanita Cooperation, Tokyo, Japan). The BIA readings were used to record body mass (kg) to body fat percentage (BF %). In addition to the direct body composition measures from the Tanita scale, fat mass index (FMI; $kg \cdot m^{-2}$) and fat-free mass index (FFMI; $kg \cdot m^{-2}$) were calculated to provide a more comprehensive assessment of body composition. Before the BIA reading, each participant was required to pass a hydration test. Each participant provided a urine sample to assess hydration levels by measuring urine specific gravity with a refractometer (V-Resourcing, Hunan, China). If participants were dehydrated (urine specific gravity > 1.025), they were given water and then provided a new urine sample to ensure accurate results on their body composition assessment.

Flexibility and functional reach test balance assessment.

Stability limits and balance during functional tasks were measured with the functional reach test.[18] The participants stood shoulder-width apart with their feet without touching the wall. They were instructed to keep their hands open, and fingers extended, parallel to the floor, and aligned with the end of the yardstick. Bending at the hips with their legs straight, each participant reached as far forward as possible along the yardstick while keeping their heels on the ground with no bending of the knees. The participants were allowed up to two practice trials and then completed three recorded trials.

The sit-and-reach test (SRT; cm) assessment measures lower back and hamstring flexibility.[10] Participants sat on the floor with their legs fully extended and their feet against the SRT box. They were instructed to extend their arms with their hands on top of each other, palms down. Next, each participant was instructed to reach forward, pushing the bracket as far as possible, keeping their hands at the same level for two seconds, without one reaching further forward than the other, completing the movement in a slow and controlled motion, and allowed up to two practice trials. The length of the bracket moved was recorded after three testing trials.

Cognitive assessment.

The FitLight Trainer (FITLIGHT Sports Corp., Aurora, ON, Canada) was used to assess cognitive response time (CRT). The FitLight Trainer is a wireless system with six sensors attached to tripods arranged in a straight line at varying heights. The protocol required participants to deactivate the lights as quickly as possible by tapping the sensor as they illuminated. Participants completed one familiarization trial consisting of 15 hits, followed by three test trials of 30 hits each. The CRT was calculated as the average response time (in seconds) across the three 30-hit test trials.

Lower body power assessment.

Lower body power was assessed using a countermovement jump on the Leonardo Mechanography force platform (Leonardo Mechanograph, Novotec Medical GmbH, Pforzheim, Germany). The two force platforms, one for the right and one for the left foot were sampled at 1000 Hz. After a demonstration that consisted of squatting down into a countermovement, jumping, and landing on both feet participants stood still on the force platform with their hands on their hips. Participants were instructed to jump as high as possible while maintaining hands on hips. The countermovement jump protocol consisted of two practice jumps and two maximum jumps. Peak countermovement jump height was used in the analysis and recorded in centimeters.

Grip strength assessment.

Grip strength was measured using an electronic hand dynamometer (Baseline 12-0286 Digital Smedley Dynamometer, Fabrication Enterprises Inc., Elmsford, NY, USA). Participant's dominant hand was recorded before starting the test. Participants maintains a 90° angle of the upper and forearm as they squeezed with maximal force for five seconds. Grip strength was assessed three times in each hand, alternating sides each trial and the order between hands (right and left) was randomized between participants. Grip strength from both left and right hands was recorded and combined for a total grip strength sum reported in kilograms per the ACSM guidelines.[10]

Isometric mid-thigh pull assessment.

Overall force-producing capabilities were evaluated with the Isometric Midthigh Pull (IMTP) using a portable isometric and a wooden platform with rubber grips with a straight bar attachment (Peak Force Systems, Mesquite, Texas USA). The dynamometer was attached to an adjustable chain connected to the platform. Participant stepped on the platform and were given instructions for the IMTP setup and execution.[19] Participants began in a standing position with their hips and knees slightly bent, attempting to maintain a knee joint angle of approximately 125º and a hip joint angle of 145º.[20] Participants positioned the bar around their mid-thigh using an alternate grip with the bar approximately at their midthigh. Participants were given three submaximal pulls at approximately 50%, 65-75%, and 80-90% of their perceived maximal effort. Two maximum effort pulls with a third pull to control for the variance between the first two. A variance of greater than 10-15 kg between the first and second pulls necessitated a third pull. Rest between trials was no less than 30 seconds. Peak force was recorded in kilograms for all maximal trials.

Muscular endurance assessment.

Muscular endurance was assessed using a maximum forearm plank. Participants were required to maintain a straight alignment from torso to feet, with their forearms placed directly under the shoulders and hands separated by about a fist's width without touching or interlocking. The assessment ended if the participant was unable to maintain proper form (e.g., raising or lowering the hips), if they reached volitional fatigue, or if they held the plank for the maximum duration of five minutes. The results, measured in seconds, were compared to normative benchmarks from a general population chart. A 5-minute cutoff was employed to balance muscular endurance evaluation with the need to prevent fatigue from impacting the performance of the cardiovascular assessment at the end.

Cardiovascular assessment.

Participants completed a 6-minute walk/run test to estimate maximal volume of oxygen consumption (Est. VO_{2max}; ml ·kg $^{-1}$ ·min^{-1}) using the following regression equation: Est. VO_{2max} = 20.05 + 0.02 (maximal run/walk distance) - 0.278 (BF%).[21] They were instructed to walk, run, or combine both as needed with the goal of covering the maximal distance possible. Participants were informed of their time as they completed each lap, approximately 196.9 meters. Instructors calculated the total distance covered during the 6-minute test.

Statistical Analysis

This study utilized both descriptive and inferential statistical approaches to examine the alignment of physical fitness assessments with ACSM classifications and the relationships between age, sex, and various health and performance variables. Percentile rankings (10th, 25th, 50th, 75th, and 90th percentiles) were calculated separately for males and females for each performance and body composition metric. All values are expressed as mean ± standard deviation (SD) unless stated otherwise. All analyses were conducted in R (version 4.1.1) and RStudio Desktop Pro (2024.09.0, Build 375.pro3).

To explore relationships between age, sex, and various health and performance variables, a two-step analytical approach was adopted. First, a series of regression analyses (simple linear regression) were conducted to assess the strength and direction of associations for each variable with age at the combined group level and by sex. Each variable was assessed for heteroscedasticity using the Breusch-Pagan test and normality of residuals was visually evaluated using Q-Q plots. The Pearson correlation coefficient (r) was calculated to quantify the linear association between age and each variable. For each model, the adjusted coefficient of determination (Adj. R^2) was used to characterize model fit. Correlation strength was interpreted as very weak ($r < 0.20$), weak ($0.2 \le r < 0.40$), moderate ($0.4 \le r < 0.60$), strong ($0.6 \le r < 0.80$), or very strong ($r \ge 0.80$).[22]

Multiple linear regression models were employed to investigate potential interactions between age and sex on each dependent variable. Age was centered (Age_C) to reduce multicollinearity and improve interpretation of main effects in the presence of interactions. This centering was justified given the substantial clustering of age in the 30-40 year range (78.2% of the sample), with the highest concentration between 30-35 years (44.9%). Two competing models were evaluated for each variable: (1) a main effects model of Sex and Age_C ($Y=\beta_0 + \beta_1*Sex + \beta_2*Age_C + \epsilon$), and (2) an interaction model including the Sex × Age_C interaction term ($Y=\beta_0 +\beta_1*Sex + \beta_2*Age_C + \beta_3*[Sex*Age_C] + \epsilon$). Sex was coded as 0 for males (reference group) and 1 for females. Models were selected based on Akaike Information Criterion (AIC), with the lowest AIC value indicating the best model fit. Interaction models that slightly improved model fit (i.e., lower AIC) and included statistically significant ($p < 0.05$) or near-significant ($p < 0.10$) interaction terms were reported in place of the main effects model.

Participants' criterion-based reference values with ACSM fitness guidelines were evaluated across several performance and body composition metrics, including BF%, SR, countermovement jump, grip strength, Plank, and Est. VO_{2max}. Criterion thresholds were set based on ACSM's classifications, where performance ratings of "Good" and "Average" or higher were considered "Within the Recommended Range." For each age group and sex category, compliance rates were calculated by dividing the number of compliant individuals by the total sample size. Aggregated compliance data were visualized using bar plots and heatmaps, where color gradients indicated levels of compliance (e.g., green for high compliance, red for low compliance).

Results

Demographics are presented in Table 1.

Percentile rankings were calculated for all fitness variables to provide within-sample benchmarks for tailoring individual goals and interventions (Table 2).

Table 1. Participant Characteristics and Descriptive Statistics.

Variable	Sex	N	Mean (± SD)		Median	Min.	Max
Age (yrs)	Male	219	37	(± 4.75)	36	31	62
	Female	86	37	(± 6.15)	35	25	64
Height (cm)	Male	219	178.01	(± 7.65)	177.80	153.67	195.58
	Female	86	163.64	(± 7.72)	163.20	138.43	180.34
Body Mass (kg)	Male	219	87.72	(± 14.94)	85.44	56.78	171.16
	Female	86	72.45	(± 14.42)	69.79	47.89	124.81
Body Mass Index (kg·m^{-2})	Male	219	27.69	(± 4.25)	27.00	20.8	51.20
	Female	86	27.08	(± 5.53)	25.80	18.5	57.10
Body Fat Percentage (%)	Male	216	20.56	(± 6.22)	20.40	5.00	38.20
	Female	85	32.86	(± 7.47)	32.80	14.3	49.50
Fat Mass Index (kg·m^{-2})	Male	216	5.83	(± 2.42)	5.59	1.04	14.07
	Female	85	9.24	(± 4.01)	8.35	2.76	28.26
Fat-Free Mass Index (kg·m^{-2})	Male	216	21.68	(± 2.09)	21.46	17.10	30.03
	Female	85	17.85	(± 1.92)	17.61	13.64	28.83
Functional Reach Test (cm)	Male	219	39.33	(± 5.89)	39.00	19	52.5
	Female	86	37.98	(± 5.76)	38.50	25	51
Sit-and-Reach Test (cm)	Male	219	24.15	(± 9.64)	24.50	0	50
	Female	86	31.91	(± 8.9)	33.50	0	47.50
Cognitive Response Time (s)	Male	219	32.47	(± 2.28)	32.12	27.65	39.43
	Female	86	33.69	(± 2.78)	33.45	28.79	44.55
Countermovement Jump (cm)	Male	216	41.38	(± 6.49)	41.15	22.86	59.18
	Female	83	30.1	(± 6.47)	29.72	12.45	49.02
Grip Strength (kg)	Male	219	100.49	(± 16.77)	100.2	29.00	155.80
	Female	86	63.12	(± 13.25)	61.25	32.10	120.90
Isometric Midthigh Pull (kg)	Male	188	223.06	(± 58.56)	221.45	0	394.60
	Female	68	134.57	(± 37.96)	132.95	0	245.80
Plank (s)	Male	216	152.94	(± 61.19)	134.00	28.00	300.00
	Female	83	119.1	(± 57.37)	120.00	0.16	276.00
Estimated VO_2max (ml·kg·min^{-2})	Male	219	43.41	(± 4.83)	43.74	19.97	54.80
	Female	86	39.11	(± 3.75)	39.01	28.71	45.63

Notes: N = number of participants; SD = standard deviation; kg·m^{-2} = kilograms per square meter; cm = centimeters; s = seconds; kg = kilograms; ml·kg^{-1}·min^{-1} = milliliters per kilogram per minute.

Table 2. Percentile Rankings by Variable and Sex.

Variable	Sex	10%	25%	50%	75%	90%
Body Mass Index ($kg \cdot m^{-2}$)	Male	23.28	24.50	27.00	29.85	32.54
	Female	21.90	23.72	25.80	29.80	33.10
Body Fat Percentage (%)	Male	12.20	16.67	20.40	24.42	29.25
	Female	24.66	28.10	32.80	38.30	41.74
Fat Mass Index ($kg \cdot m^{-2}$)	Male	2.91	4.13	5.59	7.26	9.30
	Female	5.43	6.74	8.35	11.36	13.82
Fat-Free Mass Index ($kg \cdot m^{-2}$)	Male	19.11	20.23	21.46	22.99	24.44
	Female	15.92	16.82	17.61	18.61	19.77
Functional Reach Test (cm)	Male	31.90	35.95	39.00	43.25	47.18
	Female	31.00	33.13	38.50	42.15	44.75
Sit-and-Reach Test (cm)	Male	12.00	16.75	24.50	31.25	37.00
	Female	21.25	26.00	33.50	39.00	41.25
Cognitive Response Time (s)	Male	29.98	30.88	32.12	33.94	35.68
	Female	30.59	31.68	33.45	35.06	37.08
Countermovement Jump (cm)	Male	33.27	37.34	41.15	45.21	48.90
	Female	22.66	26.29	29.72	33.66	38.51
Grip Strength (kg)	Male	80.16	89.90	100.20	111.10	120.64
	Female	49.75	54.63	61.25	69.50	76.55
Isometric Midthigh Pull (kg)	Male	163.30	185.90	221.45	252.05	300.36
	Female	89.90	114.18	132.95	159.95	171.78
Plank (s)	Male	81.00	118.75	134.00	192.75	240.50
	Female	58.40	77.50	120.00	146.50	196.80
Estimated VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	Male	39.13	41.57	43.74	46.09	48.60
	Female	33.70	37.19	39.01	42.10	43.57

Notes: $kg \cdot m^{-2}$ = kilograms per square meter; cm = centimeters; s = seconds; kg = kilograms; $ml \cdot kg^{-1} \cdot min^{-1}$ = milliliters per kilogram per minute.

Simple Linear Regression Analysis.

Fitness assessment trends across age for males and females are represented in Figures 1 and 2. Group-level and sex-specific simple linear regression output results are reported in Supplementary Table 1 and 2. Simple linear regression analyses demonstrated varying age-related trends in physical and cognitive performance across sexes. Among females, CRT significantly decreased with age ($r = 0.395$, $p < 0.001$), with each additional year associated with a 0.18-second increase in reaction time. Est. VO_{2max} indicated a steeper decline in females ($r = -0.533$, $p < 0.001$), decreasing by 0.32 $ml \cdot kg^{-1} \cdot min^{-1}$ per year of age. For males, the decline in Est. VO_2max was smaller but still significant ($r = -0.156$, $p = 0.021$), with an annual reduction of 0.16 $ml \cdot kg^{-1} \cdot min^{-1}$.

Lower-body power also indicated significant age-related decline. Countermovement jump decreased in both sexes with age, with a stronger relationship in females ($r = -0.559$, $p < 0.001$; $\beta_1 = -0.58$ cm/year) than males ($r = -0.340$, $p < 0.001$; $\beta_1 = -0.46$ cm/year). Grip strength significantly decreased with age in males ($r = -0.223$, $p = 0.001$; $\beta_1 = -0.79$ kg/year) and females ($r = -0.259$, $p = 0.016$; $\beta_1 = -0.56$ kg/year). Similarly, IMTP declined significantly with age in both sexes (males: r = -0.466, p = 0.001; β_1 = -1.91 kg/year; females: r = -0.335, p = 0.005; β_1 = -1.99 kg/year).

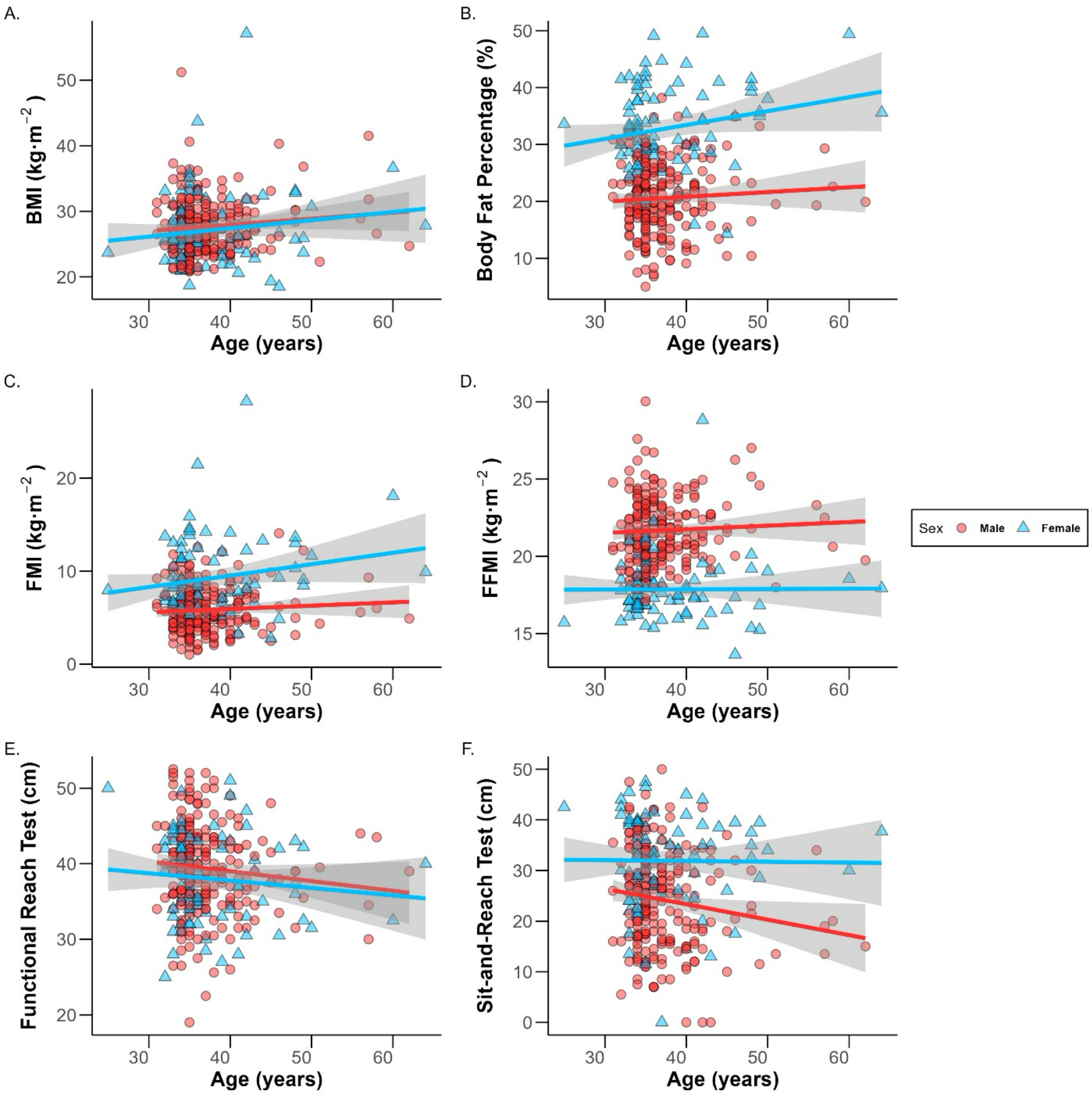

Figure 1. Associations between age and selected body composition and flexibility variables in males and females. Body composition variables include Body Mass Index (BMI; kg·m-2), body fat percentage, fat mass index (FMI; kg·m-2), and fat-free mass index (FFMI; kg·m-2). Flexibility measures include the Functional Reach Test (cm) and the Sit-and-Reach Test (cm). Regression lines for males (red) and females (blue) are plotted with confidence intervals shaded. Data are separated by sex, and the plots indicate trends observed in the studied sample. kg·m⁻² = kilograms per square meter; cm = centimeters; s = seconds; kg = kilograms.

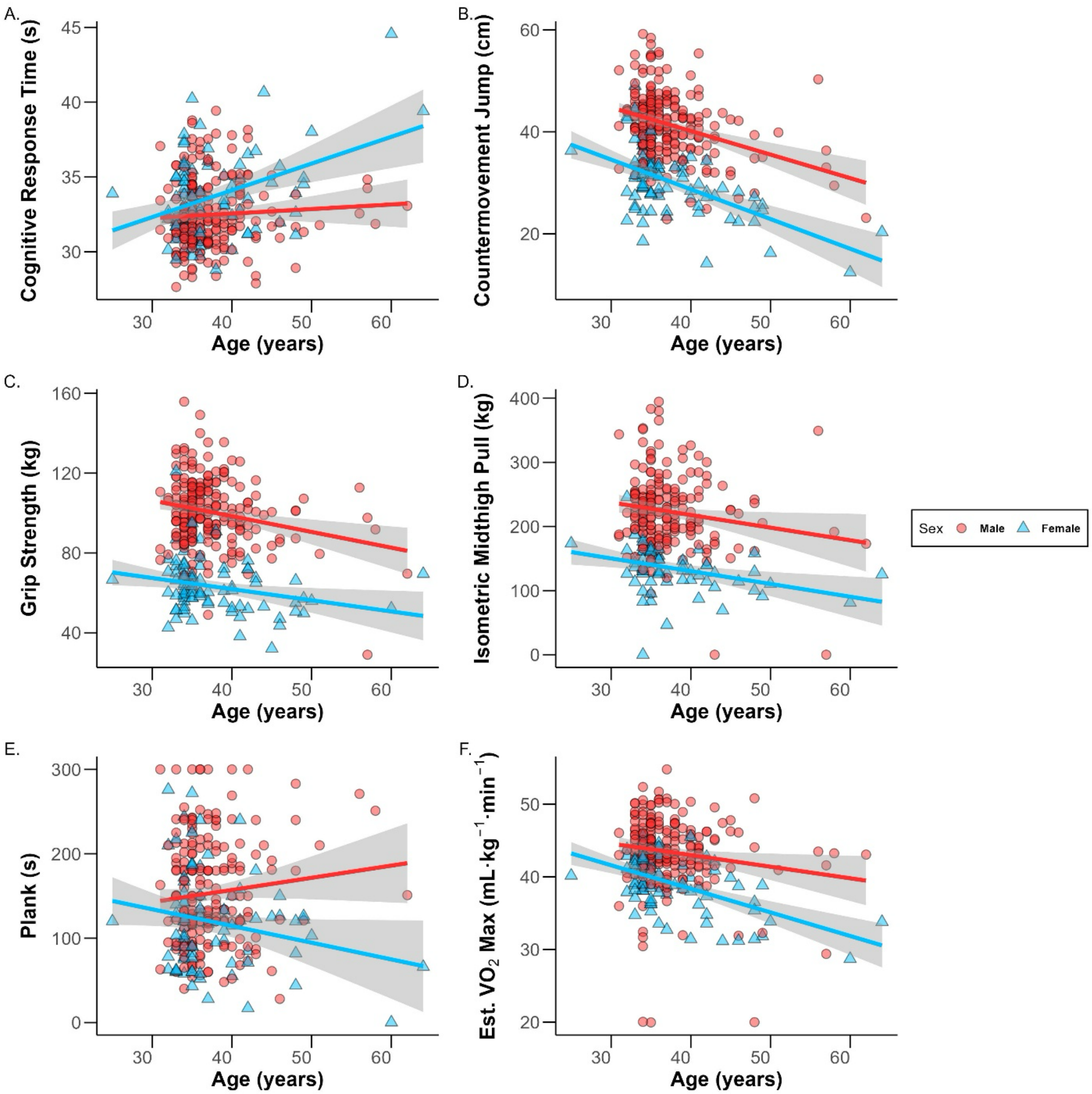

Figure 2. Associations between age and selected cognitive and performance variables in males and females. Cognitive measures include Cognitive Response Time (s). Performance variables include Countermovement Jump (cm), Grip Strength (kg), Isometric Midthigh Pull (kg), Plank (s), and Estimated VO_{2max} (mL ·kg^{-1} ·min^{-1}). Regression lines for males (red) and females (blue) are plotted with confidence intervals shaded. Data are separated by sex, and the plots indicate trends observed in the studied sample. cm = centimeters; s = seconds; kg = kilograms; ml ·kg^{-1} min^{-1} = milliliters per kilogram per minute

Trends in body composition were less consistent. In females, BF% showed a small, non-statistically significant increase with age ($r = 0.202$, $p = 0.064$), while FMI increased slightly ($r = 0.189$, $p = 0.084$). In contrast, FFMI and BMI were not statistically significantly associated with age in either sex ($p > 0.05$). Notably, plank hold duration decreased with age in females ($r = -0.213$, $p = 0.053$; $\beta_1 = -1.98$ s/year), though not significantly in males. Flexibility declined slightly in males (SRT; r = -0.150, p = 0.026; β_1 = -0.3 cm/year) but not in females. Overall, females exhibited stronger and more consistent age-related declines across VO_{2max}, CRT, and power metrics compared to males, suggesting potential sex-specific trends in physical and cognitive aging within this mid-career military cohort.

Multiple Linear Regression Analysis.

Table 3. Coefficient Estimates for Best-Fit Models: Body Composition and Flexibility

Variable	Model	Coefficient	Estimate	S.E.	95% CI	t-value	p-value
Body Fat Percentage (%)	Main Effects	β_0	20.581	0.446	19.702 - 21.459	46.111	< 0.001
		β_1	12.227	0.840	10.573 - 13.881	14.548	< 0.001
		β_2	0.762	0.379	0.016 - 1.507	2.010	0.045
Body Mass Index (kg m^{-2})	Main Effects	β_0	27.702	0.312	27.088 - 28.317	88.706	< 0.001
		β_1	-0.648	0.588	-1.806 - 0.509	-1.102	0.271
		β_2	0.546	0.265	0.024 - 1.068	2.058	0.040
Fat Mass Index (kg m^{-2})	Main Effects	β_0	5.839	0.200	5.446 - 6.233	31.887	< 0.001
		β_1	3.376	0.377	2.634 - 4.117	5.689	< 0.001
		β_2	0.365	0.170	0.031 - 0.699	1.753	0.081
Fat-Free Mass Index (kg m^{-2})	Main Effects	β_0	21.684	0.139	21.410 - 21.958	138.151	< 0.001
		β_1	-3.834	0.262	-4.35 - -3.318	-22.231	< 0.001
		β_2	0.073	0.118	-1.091 - 0.306	-0.618	0.537
Functional Reach Test (cm)	Main Effects	β_0	39.322	0.394	38.547 - 40.098	99.831	< 0.001
		β_1	-1.313	0.742	-2.773 - 0.147	-1.770	0.078
		β_2	-0.604	0.334	-1.262 - 0.054	-1.805	0.072
Sit-and-Reach Test (cm)	Main Effects	β_0	24.128	0.636	22.877 - 25.378	37.956	< 0.001
		β_1	7.831	1.198	5.474 - 10.187	6.539	< 0.001
		β_2	-0.985	0.540	-2.047 - 0.077	-1.825	0.069

Notes: S.E. = Standard error; CI = Confidence interval; kg m^{-2} = kilograms per square meter; cm = centimeters; kg = kilograms; Main Effects: $Y = \beta_0 + \beta_1 Sex + \beta_2 Age_C + \epsilon$; Interaction: $Y = \beta_0 + \beta_1 Sex + \beta_2 Age_C + \beta_3(Sex*Age_C) + \epsilon$.

Results of the multiple linear regression coefficients can be found in the Tables 3 and 4. Multiple linear regression model output comparisons by variable and type are provided in Supplementary Table 3. The multiple linear regression analysis revealed significant sex and age-related effects across body composition, flexibility, cognitive, and physical performance metrics. Adj. R^2 values ranged from 0.26 to 0.52 across models, indicating moderate explanatory power (26-52% proportion of variance for each variable was explained by sex and age). Males had significantly higher FFMI (β_1 = −3.834, p < 0.001) and lower FMI (β_1 = 3.376, p < 0.001) and BF% (β_1 = 12.227, p < 0.001) compared to females. FMI (β_2 = 0.365, p = 0.033) and BF% (β_2 = 0.762, p = 0.045) also showed small but significant increases with age, whereas FFMI did not significantly change with age (β_2 = 0.073, p = 0.536). BMI exhibited a modest but significant positive

Table 4. Coefficient Estimates for Best-Fit Models: Cognitive and Physical Performance

Variable	Model	Coefficient	Estimate	S.E.	95% CI	t-value	p-value
Cognitive Response Time (s)	Interaction	β_0	32.470	0.160	32.156 - 32.785	203.267	< 0.001
		β_1	1.171	0.301	0.579 - 1.763	3.891	< 0.001
		β_2	0.157	0.174	-0.186 - 0.501	0.903	0.367
		β_3	0.768	0.277	0.222 - 1.314	2.769	0.006
Countermovement Jump (cm)	Main Effects	β_0	41.337	0.403	40.543 - 42.130	102.564	< 0.001
		β_1	-11.130	0.765	-12.636 - -9.624	-14.547	< 0.001
		β_2	-2.648	0.343	-3.323 - -1.972	-7.715	< 0.001
Grip Strength (kg)	Main Effects	β_0	100.415	1.046	98.358 - 102.473	96.035	< 0.001
		β_1	-37.118	1.970	-40.994 - -33.241	-18.844	< 0.001
		β_2	-3.606	0.888	-5.353 - -1.859	-4.061	< 0.001
Isometric Midthigh Pull (kg)	Main Effects	β_0	222.795	3.867	215.179 - 230.410	57.612	< 0.001
		β_1	-87.484	7.509	-102.272 - -72.697	-11.651	< 0.001
		β_2	-10.258	3.323	-16.801 - -3.714	-3.087	0.002
Plank (s)	Interaction	β_0	153.122	4.069	145.114 - -48.585	37.630	< 0.001
		β_1	-33.374	7.729	-48.585 - -18.163	-4.318	< 0.001
		β_2	7.128	4.600	-1.924 - 16.180	1.550	0.122
		β_3	-16.902	6.996	-30.671 - -3.133	-2.416	0.016
Est. VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	Interaction	β_0	43.397	0.297	42.812 - 43.982	146.002	< 0.001
		β_1	-4.204	0.560	-5.306 - -3.101	-7.506	< 0.001
		β_2	-0.823	0.325	-1.462 - -0.184	-2.535	0.012
		β_3	-0.856	0.516	-1.871 - 0.159	-1.659	0.098

Notes: S.E. = Standard error; CI = Confidence interval; *cm* = centimeters; *s* = seconds; *kg* = kilograms; $ml \cdot kg^{-1} \cdot min^{-1}$ = milliliters per kilogram per minute; Main Effects: $Y = \beta_0 + \beta_1 Sex + \beta_2 Age_C + \epsilon$; Interaction: $Y = \beta_0 + \beta_1 Sex + \beta_2 Age_C + \beta_3 (Sex*Age_C) + \epsilon$

association with age ($\beta_2 = 0.546$, $p = 0.040$), while no significant sex differences were observed ($\beta_1 = -0.648$, $p = 0.271$). Sex differences were observed for flexibility metrics, with males having lower SRT scores ($\beta_1 = 7.83$, $p < 0.001$). For cognitive and physical performance, significant sex differences and age-related declines were observed. CRT showed a significant interaction between sex and age ($\beta_3 = 0.768$, $p = 0.006$) indicating that with each SD increase in age, females demonstrated an additional 0.768-second slowing in reaction time compared to males. This suggests age-related cognitive decline may be more pronounced in females within this population. GS was significantly lower in females ($\beta_1 = -37.118$, $p < 0.001$), and declined by 3.61 kg per year above the sample mean age ($\beta_2 = -3.606$, $p < 0.001$). Similar observations were observed for other performance metrics indicating significant age-related declines, with males outperforming females in the countermovement jump ($\beta_1 = -11.130$, $p < 0.001$; $\beta_2 = -2.648$, $p < 0.001$) and IMTP ($\beta_1 = -87.484$, $p < 0.001$; $\beta_2 = -10.258$, $p = 0.002$). For Plank, an age × sex interaction (β_3 = −16.901, p = 0.016) suggest greater age-related declines in core endurance performance among females. Est. VO_{2max} showed significant declines with age (β_2 = −0.823, p = 0.012) and lower values in females (β_1 = −4.204, p < 0.001), with an age-by-sex interaction approaching significance (β_3 = −0.856, p = 0.098), suggesting a steeper decline in aerobic fitness with age in females. These findings highlight that although age-related performance declines were evident across the cohort, the magnitude of decline was often more pronounced in females.

ACSM Criterion-based Reference Values.

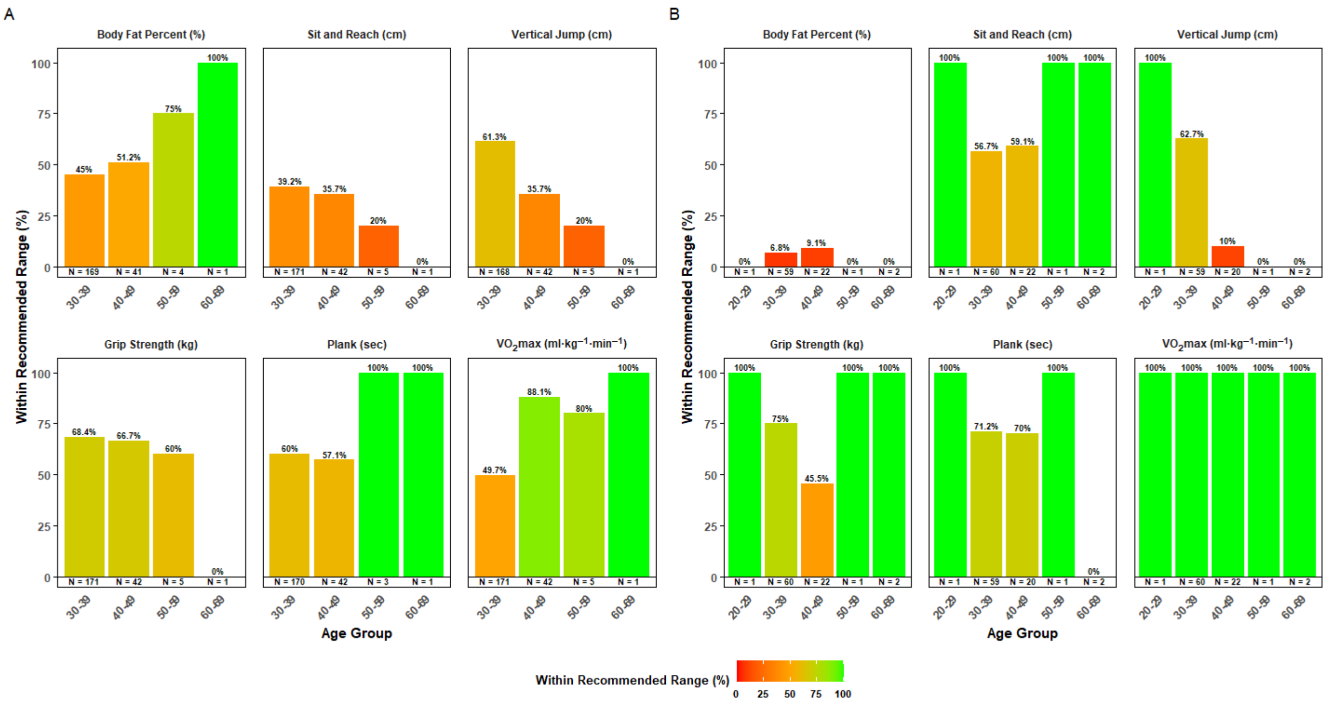

Figure 3. ACSM criterion-based rates of individuals classified as 'Within the Recommended Range' for health and performance standards across age groups and metrics for males (A; left) and females (B; right). Bar plots depict the percentage of individuals meeting thresholds corresponding to 'Good,' 'Average,' or higher performance ratings, with the sample sizes (N) indicated below each bar and percentage of individuals at or above the thresholds ('Within the Recommended Range'). Heatmap colors represent aggregated adherence levels, with gradients ranging from red (low adherence) to green (high adherence), as defined by the proportion of individuals meeting the recommended thresholds for each metric by age group (x-axis) and percentage within the range (y-axis).

Detailed breakdowns of all ACSM-based classifications across age and sex are provided in Supplementary Tables 4–9 and visually represented in Figure 3. ACSM fitness classifications revealed that a substantial portion of participants fell below recommended thresholds, particularly for body composition and cardiorespiratory fitness, although sex-specific differences were observed. For BF% among females aged 30–39, only 6.8% (n = 4) were classified as "Good" or higher, while 93.2% (n = 55) were classified as "Poor" or "Very Poor." Among females aged 40–49, 77.2% (n = 17) were classified as "Poor" or "Very Poor," 13.6% (n = 3) classified as "Fair," 9.1% (n = 2) achieving a "Very Lean" classification, and none classified as "Good" or "Excellent." In contrast, among males aged 30–39, 45% (n = 76) were "Good" or higher, and 37.9% (n = 64) were "Poor" or "Very Poor." For grip strength, 67.6% (n = 148) of males met or exceeded a "Good" classification across combined age groups. Similar results were observed for females across combined age groups with 68.6% (n = 59) achieving or exceeding a "Good" classification. Est. VO_2max ratings among males aged 30–39, 49.7% (n = 85) achieved a "Good" or higher classification, and while 6.4% (n = 11) were classified as "Poor" or "Very Poor." In contrast, 100% (n = 60) of female participants in the same age group were classified at or above "Good." For countermovement jump (Vertical Jump), most participants of both sexes scored in the mid to lower half of ACSM normative ranges. Males showed broader distribution across all plank classifications, while females clustered more around the "Fair" to "Good" categories.

Discussion

The goal of this study was to assess a range of health, fitness and cognition metrics across a broad, mid-level military and DOD-civilian cohort at the ACSC and compare the outcomes to the ACSM guidelines for physical activity, highlighting significant trends in body composition, strength, power, and endurance. This study provides actionable insights for target health and wellness programs by adding to the limited literature comparing a range of health and performance assessments other than standardized military tests in a diverse military population.

Age-related increases in BF% and FMI underscore the need for tailored interventions to maintain healthy body composition in military personnel. Age-related changes in various body composition metrics among uniformed servicemembers likely reflect physiological changes associated with aging, including a decline in metabolic rate and alterations in fat distribution. Previous research has shown that Army personnel begin to experience notable declines in physiological characteristics around the age of 30-34. Specifically, males in this age range had significant higher BF% ($p = 0.023$) compared those aged 20-24.[23] When we compare their average BF% results to ACSM guidelines, both age groups fell within the fair to poor classification range. Comparing results to evidence-based guidelines that provide simple comparisons to population norms allows for more meaningful interpretation of the data. In the current study, females exhibited 12.2% higher BF% than males on average, while males had 3.83 kg/m^2 higher FFMI and 3.38 kg/m^2 lower FMI compared to females. FFMI displayed no significant age-related or sex-dependent decline which contrasts with previous literature indicating fat-free mass (e.g., skeletal muscle tissue) typically decline with age.[24] Although no significant relationship was observed for decreases in FFMI, weak evidence of a relationship with increased fat accumulation (i.e., BF% and FMI) in females was observed. This lack of evidence for FFMI decline may be attributed to the unique characteristics of this military population, which is subject to higher fitness standards and regular physical activity requirements than the general population. Previous research has shown that participation in personal physical training outside of mandated unit training significantly contributes to cardiovascular and muscular endurance outcomes.[25] These factors could mitigate age-related declines in fat-free mass, particularly skeletal muscle tissue that are commonly observed in less active populations. However, the observed increases in BF% and FMI are consistent with previous findings suggesting proportional fat mass increases in women as they age, particularly during peri- and post-menopausal periods.[26]

Reductions in muscular strength, power, and endurance with age may compromise performance in load-bearing and high-intensity tasks critical for military operations. Grip strength and IMTP displayed pronounced declines, indicating the importance of addressing muscular strength and power preservation in older populations. These changes are often compounded by alterations in the nervous system, further reducing muscle force and power, impacting tasks such as climbing stairs or maintaining balance during unexpected movements.[27,28] Strength training for military tasks has been widely studied,[29,30] it also serves to mitigate age-related declines in muscle strength and bone density, factors mostly relevant when assessing grip strength differences between males and females.[31]

Grip strength is a common measure for evaluating muscular strength, with low cut-off points of <27 kg for men and <16 kg for women previously reported.[27] Low grip strength has also been associated with higher mortality rates and increased risk of morbidity, cognitive decline, cardiovascular disease, and institutionalization.[27] In the present study, grip strength, calculated as the sum of the left and right hands, showed a notable decline with age, decreasing by an average of 3.6 kg for each year above the mean age of 37.7 years independent of sex. These findings highlight the importance of grip strength as a critical indicator of muscular health, emphasizing the need for targeted interventions to preserve and enhance strength. By incorporating strength training and other preventative measures, it is possible to support long-term functional ability and overall quality of life.

Age-related declines in cognitive reaction time and functional fitness metrics emphasize the importance of preserving both mental agility and physical flexibility for mission success. Age was moderately associated with cognitive performance metrics, indicating slower response times with increasing age particularly in females. Limited research exists on cognitive performance tests, particularly within military populations. However, studies have shown that males tend to perform better on tests assessing manual speed and visual perception, while women excel in manual dexterity tests that measure fine motor skills.[32,33] Cognitive performance is critical for rapid decision-making and situational awareness in high-stress, time-sensitive environments such as combat scenarios or operational planning. Slower reaction times may negatively impact occupational performance by delaying critical responses, increasing risks during missions and potentially affecting team dynamics. With the increasing complexity of modern military tasks, where cognitive demands often equal or surpass physical ones, understanding cognitive decline and its impact on mission readiness is crucial. Additionally, these results highlight a gap in the literature regarding the relationship between cognitive performance metrics and broader health outcomes, including neurodegenerative risks and occupational injury rates. Future research is warranted to explore interventions such as cognitive training or integrated physical and mental conditioning programs that could mitigate age-related cognitive declines and optimize mental agility alongside physical readiness in tactical populations. Research suggests that slight increases in cognitive performance can be achieved through training, as evidenced by the effects of sports vision training on sensorimotor abilities in collegiate athletes.[34] These findings highlight the need for further research to establish the applicability of such training methods in enhancing cognitive and sensorimotor performance among military personnel.

The ACSM guidelines provide a practical framework for evaluating military personnel fitness, revealing critical trends in body composition, strength, and aerobic fitness that could impact mission readiness. For instance, a substantial percentage of individuals—particularly females across all age groups—achieved high classifications for cardiovascular fitness, underscoring the importance of maintaining aerobic capacity throughout the lifespan. However, age-related declines and low classifications in body composition metrics (e.g., BMI, BF%, and FMI) and performance measures (e.g., grip strength and countermovement jump) highlight areas for concern. Among female participants, less than 10% in the 30–39 and 40–49 age groups—most of the study's female population—achieved a BF% rating classified as 'Good' (17.5–21.0% for ages 30–39 and 19.5–23.7% for ages 40–49). Many females across all age groups fell into the 'Poor' or 'Very Poor' categories, with BF% values ≥25.8%. Similarly, a high prevalence of males in the 30–39 age category, which represented most of the study population, fell into the 'Poor' or 'Very Poor' categories for BF% and VO_{2max}. Over 50% of males in this age group did not achieve a 'Good' rating, corresponding to a BF% of 15.9–18.0% and an Est. VO_{2max} of 45.2–49.2 $ml \cdot kg^{-1} \cdot min^{-1}$. This is particularly concerning, as increased BF% and reduced VO_{2max} are strongly associated with elevated risks of cardiovascular disease, all-cause mortality, and other adverse health outcomes.[27,35,36] Furthermore, lower ACSM fitness classifications for SRT and vertical jump (i.e., countermovement jump) suggest a heightened risk of functional decline. This suggests that a substantial percentage of the warfighters in this study may be at an increased risk of these health complications, which could significantly impact mission readiness, long-term health outcomes, and healthcare costs.

Tactical population readiness extends beyond performance to include overall health and fitness. Evidence-based guidelines, such as the ACSM fitness guidelines, offer a useful and uniform way to evaluate overall health and fitness. Values like BF% can be vague on their own; classifying them with ACSM norms (e.g., fair, poor, good) allows for simple interpretation for tactical athletes or leadership. These classifications provide a clear snapshot of where individuals stand relative to the general population, making it easier to prioritize interventions.

Simple tools that communicate health status clearly are essential given the limited time and resources often available in these settings. These guidelines can help drive programming that is both effective and sustainable when combined with evidence-based exercise prescriptions shown to improve cardiovascular, muscular, and metabolic health.[37-39] Emphasizing enjoyable and accessible activities can also improve adherence, which is an important factor when designing interventions for busy professionals in high-stress environments. Ultimately, aligning assessments with broader wellness goals and presenting them in a format that's easy to understand supports both short- and long-term improvements in health and fitness readiness.

Several limitations exist in the current study. First, it was conducted as a field study at an off-campus site using multiple pieces of equipment to achieve a holistic assessment. Although testing was conducted in the same room, some data points may have been skewed if equipment was moved or required recalibration. To mitigate this, each assessment was performed in the same location on each testing day. Additionally, some participants may have engaged in physical activity prior to testing, potentially influencing their results. Furthermore, some participants were unable to complete all testing due to scheduling conflicts. Given that participants are students at Air University, factors such as academic stress and low motivation may have influenced their effort and performance during fitness assessments, potentially impacting the study's results.

This study sought to analyze comprehensive fitness assessment data to identify and report metrics for non-entry level military personnel across various fitness domains. Our results suggest that age and sex play a crucial role on performance in our participants. Age and sex significantly influence body composition suggesting that as both sexes age, it may be advantageous to maintain or implement new strategies that promote healthy body composition. Secondly, age significantly impacted performance. Research suggests it is beneficial to adhere to resistance and cardiovascular training for a lifetime to slow these changes. Lastly, sex also significantly impacted performance suggesting that hormonal and physiological differences between males and females need to be accounted for when training is developed. Continued research should investigate the influence of tailored training plans to enhance performance outcomes while addressing these innate differences.

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Supplementary Table 1. Summary of Group Bivariate Regression Models by Variable

Variable	N of Observations	Equation	r	Adj. R^2	SEE	P-value
Body Mass Index (kg ·m^{-2})	305	y = 23.64 + 0.1 * x	0.116	0.013	4.623	0.044
Body Fat Percentage (%)	301	y = 16.7 + 0.2 * x	0.116	0.013	8.562	0.045
Fat Mass Index (kg ·m^{-2})	301	y = 3.63 + 0.08 * x	0.129	0.017	3.306	0.025
Fat-Free Mass Index (kg ·m^{-2})	301	y = 20.6 + 0 * x	0.000	0.000	2.676	0.999
Functional Reach Test (cm)	305	y = 43.45 + -0.12 * x	-0.106	0.011	5.849	0.065
Sit-and-Reach Test (cm)	305	y = 32.66 + -0.17 * x	-0.087	0.008	10.03	0.130
Cognitive Reacton Time (s)	305	y = 29.25 + 0.09 * x	0.416	0.173	1.389	< 0.001
Countermovement Jump (cm)	299	y = 58.22 + -0.53 * x	-0.338	0.114	7.743	< 0.001
Grip Strength (kg)	305	y = 119.82 + -0.8 * x	-0.179	0.032	22.78	0.002
Isometric Midthigh Pull (kg)	256	y = 285.65 + -2.3 * x	-0.18	0.032	65.58	0.004
Plank (s)	299	y = 148.11 + -0.21 * x	-0.028	0.001	7.064	0.629
Est. VO_2max	305	y = 51.03 + -0.24 * x	-0.247	0.061	4.798	< 0.001

Notes: N = number of observations; SD = standard deviation; kg ·m^{-2} = kilograms per square meter; cm = centimeters; s = seconds; kg = kilograms; ml ·kg^{-1} ·min^{-1} = milliliters per kilogram per minute; r = correlation coefficient ; Adj. R^2 = Adjusted R^2; SEE = standard error of the estimate.

Supplementary Table 2. Summary of Bivariate Regression Models by Variable and Sex

Variable	Sex	N of Observations	Equation	r	Adj. R^2	SEE	P-value
Body Fat Percentage (%)	Male	216	y = 17.45 + 0.08 * x	0.062	0.001	6.218	0.368
	Female	85	y = 23.65 + 0.24 * x	0.202	0.029	7.359	0.064
Body Mass Index (kg ·m^{-2})	Male	219	y = 24.24 + 0.09 * x	0.103	0.006	4.237	0.127
	Female	86	y = 22.36 + 0.13 * x	0.139	0.008	5.511	0.201
Fat Mass Index (kg ·m^{-2})	Male	216	y = 4.5 + 0.04 * x	0.068	0.001	2.42	0.322
	Female	85	y = 4.6 + 0.12 * x	0.189	0.024	3.966	0.084
Fat-Free Mass Index (kg ·m^{-2})	Male	216	y = 20.81 + 0.02 * x	0.051	0.002	2.091	0.454
	Female	85	y = 17.79 + 0 * x	0.006	0.012	1.932	0.958
Functional Reach Test (cm)	Male	219	y = 44.15 - 0.13 * x	-0.104	0.006	5.867	0.124
	Female	86	y = 41.66 - 0.1 * x	-0.104	0.001	5.759	0.339
Sit-and-Reach Test (cm)	Male	219	y = 35.52 - 0.3 x	-0.150	0.018	9.558	0.026
	Female	86	y = 32.5 - 0.02 * x	-0.011	0.012	8.953	0.92
Cognitive Reaction Time (s)	Male	219	y = 31.33 + 0.03 * x	0.063	0.001	2.277	0.350
	Female	86	y = 26.95 + 0.18 * x	0.395	0.146	2.573	< 0.001
Countermovement Jump (cm)	Male	216	y = 58.63 - 0.46 * x	-0.340	0.111	6.114	<0.001
	Female	83	y = 52.03 - 0.58 * x	-0.559	0.304	5.394	< 0.001
Grip Strength (kg)	Male	219	y = 129.88 - 0.79 * x	-0.223	0.045	16.385	0.001
	Female	86	y = 84.16 - 0.56 * x	-0.259	0.056	12.876	0.016
Isometric Midthigh Pull (kg)	Male	188	y = 293.66 - 1.91 * x	-0.466	0.213	6.63	0.001
	Female	68	y = 209.83 - 1.99 * x	-0.335	0.099	36.03	0.005
Plank (s)	Male	216	y = 99.32 + 1.44 * x	0.103	0.006	61.009	0.130
	Female	83	y = 193.52 - 1.98 * x	-0.213	0.034	56.399	0.053
	Male	219	y = 49.35 - 0.16 * x	-0.156	0.020	4.784	0.021

Est. VO_{2max} (ml ·kg^{-1} ·min^{-1})	Female	86	y = 51.34 - 0.32 * x	-0.533	0.275	3.189	< 0.001

Notes: N = number of observations; SD = standard deviation; kg ·m^{-2} = kilograms per square meter; cm = centimeters; s = seconds; kg = kilograms; ml ·kg^{-1} ·min^{-1} = milliliters per kilogram per minute; r = correlation coefficient ; Adj. R^2 = Adjusted R^2; SEE = standard error of the estimate.

Supplementary Table 3. Summary of Model Comparisons by Variable and Type

Variable	Model	Adj. R^2	DF	F-Statistic	RSE	SSE	P-value	AIC
Body Fat Percentage (%)	Main Effects	0.42	298	109.271	6.558	12816.621	< 0.001	1991.369
	Interaction	0.42	297	73.250	6.557	12768.413	< 0.001	1992.234
Body Mass Index (BMI)	Main Effects	0.01	302	2.657	4.621	6448.601	< 0.001	1804.201
	Interaction	0.01	301	1.798	4.628	6446.534	< 0.001	1806.103
Fat Mass Index (kg ·m^{-2})	Main Effects	0.22	298	43.363	2.938	2573.584	< 0.001	1508.130
	Interaction	0.22	297	29.520	2.935	2559.408	< 0.001	1508.468
Fat-Free Mass Index (kg ·m^{-2})	Main Effects	0.41	298	248.314	2.045	1246.039	< 0.001	1289.806
	Interaction	0.41	297	71.235	2.048	15840.908	< 0.001	1291.596
Functional Reach Test (cm)	Main Effects	0.01	302	3.299	5.828	10258.337	< 0.001	1945.790
	Interaction	0.01	301	2.211	5.837	10256.419	< 0.001	1947.733
Sit-and-Reach Test (cm)	Main Effects	0.12	302	22.693	9.406	26718.325	< 0.001	2237.754
	Interaction	0.13	301	15.784	9.393	26556.045	< 0.001	2237.896
Cognitive Response Time (s)	Main Effects	0.08	302	13.717	2.389	1724.171	< 0.001	1401.870
	Interaction	0.10	301	11.902	2.363	1681.337	< 0.001	1396.198
Countermovement Jump (cm)	Main Effects	0.48	296	138.519	5.923	10383.630	< 0.001	1917.240
	Interaction	0.48	295	92.549	5.925	10355.625	< 0.001	1918.433
Grip Strength (kg)	Main Effects	0.55	302	188.368	15.471	72288.137	< 0.001	2541.324
	Interaction	0.55	301	125.481	15.486	72186.083	< 0.001	2542.893
Isometric Midthigh Pull (kg)	Main Effects	0.37	253	74.347	53.010	710954.926	< 0.001	2764.368
	Interaction	0.36	252	49.369	53.115	710953.844	< 0.001	2766.368
Plank (s)	Main Effects	0.05	296	9.455	60.265	1075030.021	< 0.001	3304.562
	Interaction	0.07	295	8.352	59.779	1054173.948	< 0.001	3300.705
Est. VO_2Max (ml ·kg^{-1} ·min^{-1})	Main Effects	0.20	302	39.929	4.410	5874.476	< 0.001	1775.761
	Interaction	0.21	301	27.691	4.398	5821.260	< 0.001	1774.985

Notes: kg ·m^{-2} = kilograms per square meter; cm = centimeters; s = seconds; kg = kilograms; ml ·kg^{-1} ·min^{-1} = milliliters per kilogram per minute; Adj. R^2 = Adjusted R^2; DF = degrees of freedom; RSE = Residual Square Error; SSE = sum of squared errors; AIC = Akiake Information Criterion; Main Effects: $Y = \beta_0 + \beta_1 Sex + \beta_2 Age_C + \epsilon$; Interaction: $Y = \beta_0 + \beta_1 Sex + \beta_2 Age_C + \beta_3 (Sex{*}Age_C) + \epsilon$.

Supplementary Table 4. ACSM Fitness Classifications for Body Fat Percentage (%) by Age Group and Sex.

Sex	Category	BF%	20-29 (*n*)	BF%	30-39 (*n*)	BF%	40-49 (*n*)	BF %	50-59 (*n*)	BF%	60-69 (*n*)
Male	Very Poor	24.9 - 33.4	0	26.4 - 34.4	29	27.8 - 35.2	8	29.2 - 36.4	1	29.8 - 36.8	0
	Poor	19.7 - 23.3	0	22.4 - 25.1	35	24.2 - 26.6	3	25.6 - 28.1	0	26.4 - 28.8	0
	Fair	15.8 - 18.6	0	19.2 - 21.6	29	21.4 - 23.5	9	23.0 - 24.9	0	23.6 - 25.6	0
	Good	11.5 - 14.8	0	15.9 - 18.4	39	18.5 - 20.8	6	20.2 - 22.3	1	21.0 - 23.0	0

	Excellent	07.9 - 10.5	0	12.4 - 14.9	20	15.0 - 17.5	7	17.0 - 19.4	2	18.1 - 20.2	1
	Very Lean	4.2 - 6.4	0	07.3 - 10.3	17	09.5 - 12.9	8	11.0 - 14.8	0	11.9 - 16.2	0
Female	Very Poor	30.5 - 38.6	1	31.5 - 39.0	29	33.4 - 39.1	13	35.0 - 39.8	1	35.6 - 40.3	2
	Poor	24.2 - 28.2	0	25.8 - 29.6	20	28.4 - 31.9	4	30.8 - 33.9	0	31.5 - 34.4	0
	Fair	20.6 - 23.4	0	22.0 - 24.8	6	24.6 - 27.5	3	27.6 - 30.1	0	28.3 - 30.8	0
	Good	16.8 - 19.8	0	17.5 - 21.0	3	19.5 - 23.7	0	22.3 - 26.7	0	23.3 - 27.5	0
	Excellent	15.1 - 16.1	0	15.5 - 16.5	1	16.8 - 18.3	0	19.1 - 20.8	0	20.2 - 22.0	0
	Very Lean	11.4 - 14.0	0	11.2 - 13.9	0	12.1 - 15.2	2	13.9 - 16.9	0	13.9 - 17.7	0

Notes: ACSM = American College of Sports Medicine; BF% = body fat percentage; Column headers (e.g., 20–29 (*n*), 30–39 (*n*)) indicate the number of participants within each age group.

Supplementary Table 5. ACSM Fitness Classifications for Sit-and-Reach (cm) Test by Age Group and Sex.

Sex	Category	cm	20-29 (*n*)	cm	30-39 (*n*)	cm	40-49 (*n*)	cm	50-59 (*n*)	cm	60-69 (*n*)
Male	Poor	≤ 24	0	≤ 22	71	≤ 17	15	≤ 15	2	≤ 14	0
	Fair	25 - 29	0	23 -27	33	18 - 23	12	16 - 23	2	15 - 19	1
	Good	30 - 33	0	28 - 32	29	24 - 28	3	24 - 27	0	20 - 24	0
	Very Good	34 - 39	0	33 - 37	20	29 - 34	9	28 - 34	1	25 - 32	0
	Excellent	≥ 40	0	≥ 38	18	≥ 35	3	≥ 35	0	≥ 33	0
Female	Poor	≤ 27	0	≤ 26	16	≤ 24	6	≤ 24	0	≤ 22	0
	Fair	28 - 32	0	27 - 31	10	25 - 29	3	25 - 29	0	23 - 26	0
	Good	33 - 36	0	32 - 35	12	30 - 33	2	30 - 32	0	27 - 30	1
	Very Good	37 - 40	0	36 - 40	14	34 - 37	4	33 - 38	1	31 - 34	0
	Excellent	≥ 41	1	≥ 41	8	≥ 38	7	≥ 39	0	≥ 35	1

Notes: ACSM = American College of Sports Medicine; cm = centimeters; Column headers (e.g., 20–29 (*n*), 30–39 (*n*)) indicate the number of participants within each age group.

Supplementary Table 6. ACSM Vertical Jump by Age Group and Sex.

Sex	Category	Inches	20-29 (*n*)	30-39 (*n*)	40-49 (*n*)	50-59 (*n*)	60-69 (*n*)
Males	Very Poor	<8	0	0	0	0	0
	Poor	8-12	0	3	4	1	1
	Below Average	12-16	0	62	23	3	0
	Average	16-20	0	87	13	1	0
	Above Average	20-24	0	16	2	0	0
	Very Good	24-28	0	0	0	0	0
	Excellent	>28	0	0	0	0	0
Females	Very Poor	<4	0	0	0	0	0
	Poor	4-8	0	1	1	1	2
	Below Average	8-12	0	21	17	0	0
	Average	12-16	1	33	2	0	0
	Above Average	16-20	0	4	0	0	0

	Very Good	20-24	0	0	0	0	0
	Excellent	>24	0	0	0	0	0

Notes: ACSM = American College of Sports Medicine; Column headers (e.g., 20–29 (*n*), 30–39 (*n*)) indicate the number of participants within each age group.

Supplementary Table 7. ACSM Fitness Classifications for Grip Strength by Age Group and Sex.

Sex	Category	kg	20-29 (*n*)	kg	30-39 (*n*)	kg	40-49 (*n*)	kg	50-59 (*n*)	kg	60-69 (*n*)
Male	Poor	≤ 83	0	≤ 83	19	≤ 79	5	≤ 75	1	≤ 72	1
	Fair	84 - 94	0	84 - 94	35	80 - 87	9	76 - 83	1	73 - 83	0
	Good	95 - 103	0	95 - 103	40	88 - 96	9	84 - 91	1	84 - 90	0
	Very Good	104 - 114	0	104 - 114	41	97 - 107	13	92- 100	1	91 - 99	0
	Excellent	≥ 115	0	≥ 115	36	≥ 108	6	≥ 101	1	≥ 100	0
Female	Poor	≤ 51	0	≤ 50	4	≤ 48	5	≤ 44	0	≤ 40	0
	Fair	52 - 57	0	51 - 57	11	49 - 53	7	45 - 48	0	41 - 44	0
	Good	58 - 62	0	58 - 62	13	54 - 60	2	49 - 53	0	45 - 47	0
	Very Good	63 - 69	1	63 - 70	16	61 - 68	5	54 - 60	1	48 - 53	1
	Excellent	≥ 70	0	≥ 71	16	≥ 69	3	≥ 61	0	≥ 54	1

Notes: ACSM = American College of Sports Medicine; kg = kilograms.; Column headers (e.g., 20–29 (*n*), 30–39 (*n*)) indicate the number of participants within each age group.

Supplementary Table 8. ACSM Fitness Classifications for Plank by Age Group and Sex.

Sex	Category	Seconds	20-29 (*n*)	30-39 (*n*)	40-49 (*n*)	50-59 (*n*)	60-69 (*n*)
Male	Very Poor	0 - 79	0	15	5	0	0
	Poor	80 - 97	0	17	5	0	0
	Fair	98 - 122	0	36	8	0	0
	Good	123 - 157	0	36	6	0	1
	Excellent	158 - 201	0	29	9	0	0
	Superior	≥ 201	0	37	9	3	0
Female	Very Poor	0 - 35	0	1	1	0	1
	Poor	36 - 63	0	10	2	0	0
	Fair	64 - 84	0	6	3	0	1
	Good	85 - 108	0	10	1	1	0
	Excellent	109 - 142	1	15	8	0	0
	Superior	≥ 143	0	17	5	0	0

Notes: ACSM = American College of Sports Medicine. Column headers (e.g., 20–29 (*n*), 30–39 (*n*)) indicate the number of participants within each age group.

Supplementary Table 9. ACSM Cardiorespiratory Fitness Classifications (VO_{2max}) by Age Group and Sex.

Sex	Category	VO_{2max} (ml·kg^{-1} min^{-1})	20-29 (*n*)	VO_{2max} (ml·kg^{-1} min^{-1})	30-39 (*n*)	VO_{2max} (ml·kg^{-1} min^{-1})	40-49 (*n*)	VO_{2max} (ml·kg^{-1} min^{-1})	50-59 (*n*)	VO_{2max} (ml·kg^{-1} min^{-1})	60-69 (*n*)
Male	Very Poor	36.7 - 29.0	0	27.2 - 32.7	6	24.2 - 29.0	1	20.9 - 24.4	0	12.4 - 21.2	0
	Poor	38.1 - 43.5	0	34.1 - 38.5	5	30.5 - 34.6	2	26.1 - 29.5	1	22.4 - 25.7	0
	Fair	44.9 - 49.9	0	39.6 - 43.8	75	35.7 - 38.9	2	30.7 - 33.8	0	26.6 - 29.1	0
	Good	50.2 - 55.1	0	45.2 - 49.2	70	40.3 - 45.0	22	35.1 - 39.7	0	30.5 - 34.5	0
	Excellent	57.1 - 61.8	0	51.6 - 56.5	15	46.7 - 52.1	15	41.2 - 45.6	4	36.1 - 40.3	0

	Superior	≥ 66.3	0	≥ 59.8	0	≥ 55.6	0	≥ 50.7	0	≥ 43.0	1
Female	Very Poor	21.7 - 26.2	0	19.0 - 22.5	0	17.0 - 20.0	0	16.0 - 18.3	0	13.4 - 15.6	0
	Poor	28.6 - 33.6	0	24.1 - 27.4	0	21.3 - 24.1	0	19.1 - 21.2	0	16.5 - 18.4	0
	Fair	34.6 - 38.9	0	28.2 - 31.1	0	24.9 - 27.7	0	21.8 - 24.4	0	18.9 - 20.5	0
	Good	40.6 - 44.7	1	32.2 - 36.1	4	28.7 - 32.4	5	25.2 - 27.6	0	21.2 - 23.8	0
	Excellent	46.5 - 51.3	0	37.5 - 41.4	33	34.0 - 38.4	7	28.6 - 32.0	0	24.6 - 27.0	0
	Superior	≥ 56	0	≥ 45.8	23	≥ 41.7	10	≥ 35.9	1	≥ 29.4	2

Notes: ACSM = American College of Sports Medicine; ml ·kg^{-1} ·min^{-1} = milliliters per kilogram per minute; Column headers (e.g., 20–29 (*n*), 30–39 (*n*)) indicate the number of participants within each age group.